LABORATORY DIRECTIONS

FOR AN

ELEMENTARY COURSE

IN

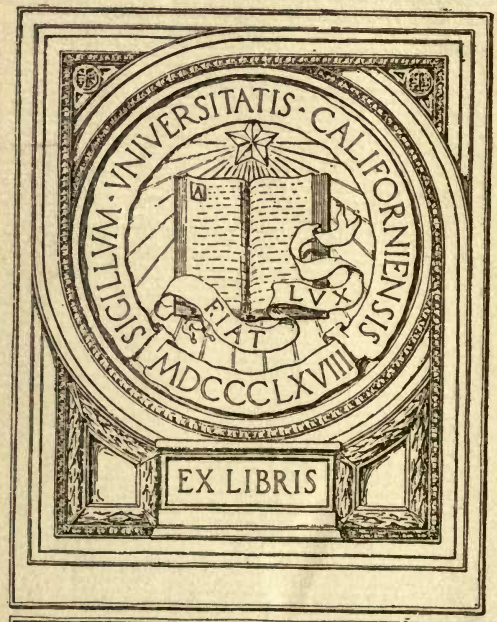
GENERAL ZOOLOGY

FOURTH EDITION

BY

H. J. VAN CLEAVE

PUBLISHED BY
THE U. OF I. SUPPLY STORE
1922



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PREFACE

These laboratory directions represent the outline of the laboratory course in general zoology as developed in the University of Illinois. The original plan of the course was formulated by Professors Henry B. Ward and Charles Zeleny. Individual outlines throughout the course represent the work and suggestions of numerous persons who have, at various times, been connected with the instructional staff in general zoology. The form found in the present volume is the result of many revisions and alterations of the several mimeographed and printed editions which have been used with classes through a period of a considerable number of years. In recent revisions the cooperation of Professor V. E. Shelford has been especially valuable.

An attempt has been made to secure a fair distribution of emphasis through a number of the more important aspects of the subject.

The directions are so organized that the field work and laboratory study based upon it may be used either at the opening or toward the close of the course, depending upon the time of year when the course is started. More work is outlined than is usually covered in a half year course, thus allowing some choice of materials on the part of the instructor. A number of the outlines are intentionally brief. These offer opportunity of directing the student in a comparative study of forms closely related to others which have been treated in greater detail.

The writer is indebted to Professor S. H. Gage for the use of the figure of the compound microscope.

H. J. Van Cleave.

Zoological Laboratory,
University of Illinois.
Urbana.

EQUIPMENT

The following equipment must be purchased at the supply stores before your first laboratory period:

I. Zoology I Packet, Containing:

(1) 4 H drawing pencil

(2) Pencil eraser

(3) Cloth for wiping glass slides, etc.

(4) 3 microscope slides

(5) 10 square coverglasses

(6) Note book; National Loose Leaf 3810½ or 3810

(7) 30 sheets Zoology drawing paper

(8) 40 sheets ruled note paper

II. Zoology Dissecting Set. Must contain the following: 1 pair fine pointed dissecting scissors, 1 scalpel, 2 dissecting needles, 1 pair forceps, 1 millimeter rule. Students expecting to take Zoology II should get a larger set of better quality.

III. Pen and Ink or Fountain Pen

IV. Small Individual Towel

V. Principles of Animal Biology by Shull, LaRue and Ruthven

VI. Laboratory Outline for Zoology I

DIRECTIONS FOR LABORATORY WORK

I. General Conduct

1. Remember that other people are working near you. Be careful to make as little disturbance of any sort as is absolutely necessary.

2. All work must be done independently, both in the field and in the laboratory. This applies to notes and drawings equally. *Any work copied from any source other than your own direct observations will be referred to the students' honor commission.*

3. *All work must be done in the laboratory.* Under no condition will permission be granted to finish or make up work outside the laboratory.

4. The note book bearing name, section and desk number on the inside of the *front cover* is to be left on the table at the end of each laboratory period.

5. In connection with the foregoing rule no notes may be removed from the laboratory until they have received a final grade except in rare cases under special arrangements with the instructor in charge.

6. Learn to work independently. When you have a question, the answer to which is not directly available from the study of your specimen, read ahead several sentences in the outline before asking for information. Look in the Glossary before asking for the meaning of any term.

7. In getting material from the preparation table always ask an Assistant for it. Very often the cultures and material are of such a nature that great care must be exercised to prevent destruction.

II. Laboratory Records

A. drawings

1. All laboratory drawings are to be in pencil and fully labelled in pencil.

2. Outline drawings showing boundaries of structures with clear cut, continuous lines (not sketched) are required except

where finer structure is to be shown. Indicate such finer structure by fine dots. No other kind of shading will be accepted.

3. Drawings must be upon the approved paper included in the Zoology I packet. Use but one side of the drawing paper.

4. Each page of drawings should bear a general subject label at the top of the page. Use care in arranging the drawings. Each individual drawing must be accompanied by a descriptive label, above or below the drawing, and in addition, details and individual parts must be pointed out. All labels must be written or printed parallel to the top of the page. Comments and explanations of a few words in length should be added to any drawing in addition to the other labels if the meaning of the drawing is not clear without such explanations. A solid or broken line should connect each structure with its special label. Study the drawing of the microscope on page 33 for method of labeling. In laboratory drawings the names of parts should never be written upon the drawing of that part but should be to one side.

B. NOTES

1. Notes are to be written only where indicated by "notes required."

2. The notes are to be in ink upon the ruled paper for that purpose included in the Zoology I packet. Use one or both sides of the ruled paper as you may prefer.

3. Questions in the outline are not to be answered with "Yes" or "No," but in each case a full statement of observations and conclusions must be given. Never copy parts of the laboratory directions in your notes.

4. Many questions in the outline are intended to direct the attention along definite lines and to stimulate thought. For these no notes are required.

C. ARRANGEMENT OF WORK IN NOTEBOOK

1. Each page of finished drawings will be stamped with an official stamp. After the drawings have been graded a check

mark will be placed after one of the words "pass," "not pass," or "excellent," indicating that the work has received a final grade.

2. All drawings and notes not yet graded must be kept in the front of the book in the order in which the work was done in the laboratory. Drawings and notes on the same study must be kept together, the drawings preceding the notes.

3. All work which has received a final grade must be transferred to the back of the book and *kept in proper order.*

4. Notebooks must be ready for inspection at all times. At each laboratory period the work should be entered properly.

5. Drawings and notes failing in any way to comply with any of these requirements will not be accepted and will not be graded.

III. Absence

1. If you are absent, or for any other reason have not completed the work outlined for the class, the work must be made up within one week from the time it is finished by the class, otherwise full credit will not be given. An excuse for absence properly signed by the Dean of Men or the Dean of Women constitutes the only basis for granting an extension of the time limit for full credit upon finished back work.

AQUATIC COLLECTING TRIP

1. The object of this work is to learn how to study and collect animals in the field, in their natural environment.

2. The field work is conducted on the same general plan as the laboratory work.

3. Each student is required to do individual work.

4. A full record of your observations is to be made in your note book while in the field.

5. Collect representatives of all kinds of animals found and large numbers of such forms as especially instructed to secure.

6. Absences do not excuse you from the work of these trips. The work must be made up as early as possible. This means in-

convenience both to student and to instructor, therefore do not miss a field trip if it can be avoided.

7. Tardiness counts as absence on these excursions, as the class starts promptly on the hour.

8. For aquatic collecting each student should have the following equipment, the first two items of which are furnished by the laboratory:

(1) A dip-net

(2) A quart Mason fruit jar with lid and rubber

(3) A pair of forceps with string attached

(4) CAR FARE

(5) Notepaper and pen or pencil

9. In the laboratory before the trip you will be given definite directions for note taking, and all field notes must conform to the directions as given.

10. The use of the dip-net will be demonstrated in the field before the collecting begins.

11. Write a general description of the region before you begin to collect. Describe fully and carefully the main features of the locality examined. This should be full enough to give a stranger a fair idea of the locality. It should include the approximate size of the stream, character of its banks, bottom, depth of water, vegetation, etc.

12. Fill the Mason jar two-thirds full of water before beginning to collect, and preserve the animals collected in the jar.

13. Wash the mud from the net as directed before attempting to sort over and examine the collection. Sort the materials upon the bank of the stream, in the net, and throw the refuse back into the stream.

14. Rinse out the net before leaving the field.

15. Before returning to the laboratory be sure you have everything with which you started.

References

Needham, Jas. G. and Lloyd, J. T. 1916. The Life of Inland Waters. Comstock Publ. Co.

Shelford, Victor E., 1913. Animal Communities in Temperate America. University of Chicago Press.

KEY TO THE PHYLA AND THE MORE COMMON CLASSES AND ORDERS OF ANIMALS, CHIEFLY AQUATIC, IN THE REGION OF URBANA, ILLINOIS

Directions For Using Key. The use of the following key involves a series of choices between two contrasting possibilities, thereby making necessary a complete chain of observations and conclusions. If any one of these is incorrect there is no possibility of making a correct final determination so the work must be started from the beginning again. For this reason care should be taken at each step to avoid "getting off the track." Always make direct observations upon the animal rather than rely on memory or on what some one else tells you.

In using the key the two numbers at the left refer to the two contrasting possibilities. Thus an attempt to classify an earthworm will start at 1 by reading the description there to see if it agrees with the facts of structure in the earthworm. The statement under 1 agrees with the facts discovered by examination of the specimen so the 3 at the end of the line indicates the next step to be tried. Since the earthworm is bilaterally symmetrical step 3 must be disregarded and its alternative 6 used. Then comes the choice between 7 and 15, and so on until the name of the phylum is reached. After the name of the phylum, is given a page number which refers to a key for distinguishing the smaller subdivisions of the phylum. In most cases classes and orders are given. The limit beyond which this key may not be used is indicated by the lack of a reference number at the end of a line following the name of a Class or an Order.

Laboratory notes on the work in classification are to be kept in the following manner: Make a record of the steps taken (disregarding the alternatives which have been discarded as not applicable to the specimen in question). Use a line for each number accepted and after the number indicate by a brief statement some one fact (or more) which led you to accept that particular step. In so far as possible make these statements in your own

words rather than copy the words of the key. For example, the notes on the earthworm would be as follows:

1—visible to unaided eye

6—bilaterally symmetrical

15—segmented

16—like a worm, without appendages

17—short bristles on segments; Phylum Coelhelminthes, Class Annelida

V-4—segmented

6—setae regularly arranged around segments. Subclass Chaetopoda. Order Oligochaetae. Common name, Earthworm.

After one or two specimens in the same general group have been identified the descriptions may be omitted and numbers only given with the names of the Phylum, Class, Order, etc. For example, if a snail and a mussel are both identified the descriptions accompanying the numbers of the steps need be given in only one instance leading to the Phylum Mollusca.

KEY TO THE PHYLA

1. (2) Animals composed of various organs and tissues, usually large enough to be seen without the microscope (the Metazoa) 3

2. (1) Animals consisting of single cells or of a group of cells, all of which perform the same functions. Microscopic in size. PHYLUM PROTOZOA..... (see page 16)

3. (6) Body either very irregular in form or radially symmetrical, but never arranged in spiral form..... 4

4. (5) Body more or less indefinite in form. Body wall pierced by numerous small openings (incurrent pores) which lead into internal cavities. The internal cavities also connect with the exterior by one or more larger openings, the oscula.
PHYLUM PORIFERA..... (see page 16)

5. (4) Body radially symmetrical; body wall not pierced by pores. Body composed essentially of two layers of cells without a cavity between them. Inner layer forms digestive system. Anus wanting. Parts of the body not usually arranged in five or multiples of five. PHYLUM COELENTERATA.....(see page 16)

6. (3) Body usually bilaterally symmetrical, or in part spirally coiled, never radially symmetrical..... 7

7. (15) Body not divided into segments. (In determining this point examine various surfaces of the body. Wings and other structures frequently obscure evidences of segmentation on the dorsal surface)..... 8

8. (11) Body usually large, not worm-like..... 9

9. (10) Completely or partially encased in a limy shell composed of one or two pieces. Soft parts of body inside shell either bilaterally symmetrical or in part spirally coiled. Ventral surface provided with a heavy muscular locomotor organ, the foot. PHYLUM MOLLUSCA .....(see page 17)

10. (9) With an axial skeleton consisting of a skull and vertebral column. Nearly always with two pairs of jointed appendages. Central nervous system entirely dorsal to alimentary canal. PHYLUM CHORDATA, SUB-PHYLUM VERTEBRATA-(see page 22)

11. (8) Body small, worm-like, not provided with shell, skeleton, or jointed appendages.....12

12. (13) Body flattened dorso-ventrally. Alimentary canal consisting of a pharnyx and a branching intestine without any anus. PHYLUM PLATHELMINTHES.....(see page 17)

13. (12) Body cylindrical or flattened. Alimentary canal always terminating posteriorly in an anal opening.....14

14. (15) Body not segmented, covered with cuticula. PHYLUM COELHELMINTHES, CLASS NEMATHELMINTHES.....
.....(see page 17)

15. (7) Body segmented.....16

16. (19) Without jointed appendages; worm-like.....17

17. (18) With bristles arranged on certain segments (if no bristles then a sucker on each end of body); without tracheae or spiracular openings, never with large tufts of bristles at one end of body.

PHYLUM COELHELMINTHES, CLASS ANNELIDA.....(see page 17)

18. (17) With tracheae and tracheal gills or spiracular openings; often with large tufts of bristles at one end of body; with a head well differentiated and always with some form of antennae and mouth parts. PHYLUM ARTHROPODA, CLASS INSECTA (larvae) .....(see page 17)

19. (16) With jointed appendages at least on extreme anterior segments. PHYLUM ARTHROPODA.....(see page 17)

I. Phylum Protozoa

1. (2) No locomotor structures in adult stage; parasitic .....CLASS SPOROZOA

2. (1) Special structures for locomotion..... 3

3. (4) Temporary lobes (pseudopodia) protruded for locomotion .....CLASS RHIZOPODA

4. (3) Permanent processes (cilia or flagella) from the surface of body for locomotion..... 5

5. (6) Numerous short protoplasmic processes (cilia) .....CLASS CILIATA

6. (5) Small number of long thread-like protoplasmic processes (flagella).....CLASS FLAGELLATA

II. Phylum Porifera

The Phylum Porifera is represented in fresh water by but a single family SPONGILLIADE belonging to the ORDER SILICISPONGIAE.

III. Phylum Coelenterata

Nematocysts present. Polyp without ectodermal esophagus Solitary polyps without medusae or medusa buds.....
.....CLASS HYDROZOA, ORDER HYDRARIAE

IV. Phylum Plathelminthes

1. Free living flatworms with body covered with cilia. CLASS TURBELLARIA 2

2. Digestive system with three main branches, one toward the head and two running posteriorly..... ORDER TRICLADIDEA

V. Phylum Coelhelminthes

1. (4) Worms with cylindrical bodies, not segmented. Covered with cuticula. CLASS NEMATHELMINTHES..... 2

2. (3) A longitudinal lateral line on each side of body. Body usually tapering at one end..... ORDER NEMATODA

3. (2) Without lateral line. Adults live in water, larvae are parasitic in insects. Body practically uniform diameter throughout ..... ORDER GORDIACEA

4. (1) Body segmented, without jointed appendages. CLASS ANNELIDA 5

5. (6) Body with anterior and posterior suckers. Nearly always without setae..... SUB-CLASS HIRUDINEI

6. (5) Setae present and regularly distributed around each segment..... SUB-CLASS CHAETOPODA, ORDER OLIGOCHAETAE

VI. Phylum Mollusca

1. (2) Body without a distinct head, usually bilaterally symmetrical. Bivalve shell. Mantle bilobed..... CLASS ACEPHALA

2. (1) Molluscs with body always asymmetrical, frequently spiral. Shell in one piece..... CLASS GASTEROPODA

VII. Phylum Arthropoda

1. (44) Head provided with a single pair of jointed antennae in addition to any feeler-like organs which are *attached* immediately around the mouth opening..... 2

2. (3) Without distinctly jointed appendages on the thorax, often with non-jointed appendages. Entirely legless or with abdominal prolegs. Head frequently reduced and retracted within the pointed apex of the thorax.....
..... CLASS INSECTA, ORDER DIPTERA (larvae)

3. (2) Thorax bearing jointed legs..... 4

4. (5) More than four pairs of legs.....CLASS MYRIAPODA

5. (4) With two, three, or four pairs of legs..... 6

6. (25) With one or two pairs of wings used in flight or at least capable of free movement. Usually three pairs of legs. CLASS INSECTA 7

7. (10) Two pairs of wings, unlike in structure..... 8

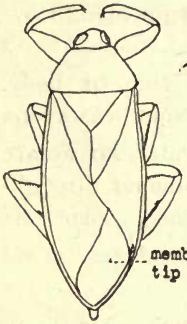

Fig. 1
Giant water bug

Fig. 2
Back swimmer

Fig.3
Water boatman

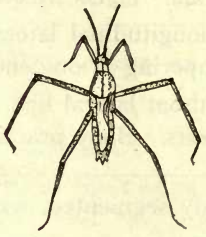

Fig. 4
Water strider

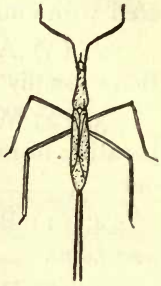

Fig. 5
Water scorpion

8. (9) Front wings leathery at base and membranous at tip, often overlapping. Mouth parts formed for sucking (see figs. 1 to 5).....ORDER HEMIPTERA

Fig. 6
Larva of a water scavenger beetle

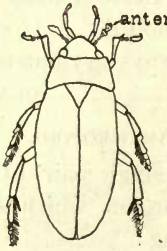

Fig. 7
Water scavenger beetle

Fig. 8
Predaceous water beetle

Fig. 9
Larva of predaceous beetle

Fig. 10
Whirligig beetle

9. (8) Front wings of same texture throughout, horny or leathery (elytra) always meeting in a straight line down the middle of the back (see fig. 7).....ORDER COLEOPTERA

10. (7) Two pairs of wings similar, membranous.....11

11 (12) Last joint of the tarsi bladder-like or hoof-like in form and without claws.....ORDER PHYSOPODA

12. (11) Last joint of tarsi not bladder-like.....13

13. (14) Wings entirely, or for the greater part, clothed with scales. Mouth parts for sucking.....ORDER LEPIDOPTERA

14. (13) Wings transparent and naked or thinly clothed with scales 15

15. (16) Mouth parts a jointed tube for sucking, arising from hinder part of ventral surface of head.....ORDER HEMIPTERA (Homoptera)

16. (15) Mouth parts not united to form sucking beak. Wings net veined with very numerous veins and cross veins.....17

17. (24) Tarsi of less than five segments.....18

18. (21) Antennae inconspicuous, awl-shaped, short, slender 19

19. (20) First and second pairs of wings of nearly the same length. Tarsi three jointed.....ORDER ODONATA

20. (19) Second pair of wings either small or wanting. Tarsi four jointed .....ORDER EPHEMERIDA

21. (18) Antennae usually conspicuous.....22

22. (23) Tarsi two or three jointed. Second pair of wings broader at base than first pair or at least as large as the first pair .....ORDER PLECOPTERA

23. (22) Tarsi four jointed. Wings equal in size.....ORDER ISOPTERA

24. (17) Tarsi with five segments. Abdomen with hair-like, many jointed, anal filaments.....ORDER EPHEMERIDA (in part)

25. (6) Wings wanting, or in some cases represented by immovable rudiments, the wing pads.....26

26. (27) With typically three pairs of legs. Head, thorax, and abdomen usually distinct; head always distinct. General body form resembling that of adult insects. CLASS INSECTA (nymphs, larvae, pupae, and a few wingless adults).....28

27. (26) Usually with four pairs of legs; in some cases with two or three pairs but in these head, thorax, and abdomen are all fused together. Respiration never by means of gills ..... CLASS ARACHNIDA

28. (33) Abdomen bearing prolegs on at least some somites 29

29. (30) Abdomen with five pairs of prolegs and with no spiracles at apex of abdomen ..... ORDER LEPIDOPTERA (larvae)

30. (29) Prolegs on last abdominal somite only 31

31. (32) Abdominal segments each with a pair of long lateral filaments or provided with conspicuous tufts ..... ORDER NEUROPTERA (larvae)

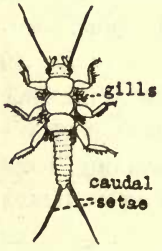

Fig. 11
Stonefly nymph

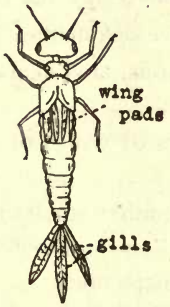

Fig. 12
Damselfly nymph

Fig. 13
Dragonfly nymph

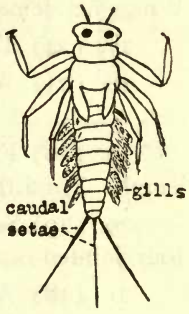

Fig. 14
Mayfly nymph

32. (31) Abdominal segments without long lateral filaments or conspicuous tufts; often with minute gill filaments. Cylindrical larvae, generally living in portable cases ..... ORDER TRICHOPTERA (larvae)

33. (28) No prolegs on abdomen 34

34. (35) Labium, when extended, much longer than head; at rest folded upon itself like a hinge and extending backward between the bases of the forelegs ..... ORDER ODONATA (nymphs)

35. (34) Labium not capable of extension beyond head 36

36. (43) Biting mouth-parts 37

37. (40) Two or three conspicuous caudal setae. (Some larvae with two projections from the posterior extremity of the abdomen have no gills on either thorax or abdomen. These are Coleoptera (larvae). If gills are present along sides of either thorax or abdomen go on with 38).....38

38. (39) Three caudal setae; gills on sides or abdomen; tarsal claws single (see fig. 14).....ORDER EPHEMERIDA (nymphs)

39. (38) Caudal setae usually two; gills mainly under thorax. Tarsal claws two (see fig. 11).....
.....ORDER PLECOPTERA (nymphs)

40. (37) With no caudal setae.....41

41. (42) Abdominal segments provided with long lateral filaments or tufts of hair-like projections along either side, or in some cases the last two abdominal segments only are supplied with lateral rows of hair-like projections (see fig. 9).....
.....ORDER COLEOPTERA (larvae)

42. (41) Abdomen ending in a median non-segmented tail-like process.....ORDER NEUROPTERA (larvae, in part)

43. (36) Mouth parts in the form of a jointed beak directed backward between the bases of the forelegs, often closely applied to body.....ORDER HEMIPTERA (nymphs)

44. (1) Head provided with two pairs of antennae in addition to any feeler-like organs which occur in the region immediately around the mouth opening. Never with wings. Respiration by means of gills, or in some small forms directly through the skin. Mostly aquatic. CLASS CRUSTACEA.....45

45. (50) With a bivalve shell hinged along dorsal surface, covering at least part of body and enclosing not only body wall but also the appendages.....46

46. (49) Entire body, including appendages and head, enclosed in a shell; resembling a small mussel.....47

47 (48) With but two pairs of trunk appendages.....
.....SUBCLASS OSTRACODA

48. (47) With ten or more pairs of trunk appendages ..... SUBCLASS PHYLLOPODA, ORDER BRANCHIOPODA

49 (46) Bivalve shell covering only part of body and frequently ending posteriorly in a pointed spine. Head not enclosed in the shell and bearing large, fringed antennae used in swimming ..... SUBCLASS PHYLLOPODA, ORDER CLADOCERA

50 (45) Body covering firm and "sell-like" but not a hinged, independent continuous shell covering the body 51

51. (58) Eyes paired 52

52 (57) Head, thorax and abdomen all bearing appendages. SUBCLASS MALACOSTRACA 53

53. (54) Eyes on the end of a movable stalk. Head and thorax fused and covered on sides and dorsal surface by a single shell, the carapace. Five pairs of walking legs ..... ORDER DECAPODA

54. (53) Eyes not stalked 55

55. (56) Body dorso-ventrally flattened ..... ORDER ISOPODA

56 (55) Body almost cylindrical or compressed laterally ..... ORDER AMPHIPODA

57 (52) Abdomen lacking appendages; carapace lacking; appendages flat, leaf-like ..... SUBCLASS PHYLLOPODA, ORDER BRANCHIOPODA

58. (51) A single eye in front of the head ..... SUBCLASS COPEPODA

VIII. PHYLUM CHORDATA

Subphylum Vertebrata

1. (4) Body covered with scales or plates, (except in fishes with smooth skin) with or without rayed fins 2

2. (3) Scales or plates dry and hard. Breathe by lungs. Without rayed fins ..... CLASS REPTILIA

3. (2) Scales or plates moist (rarely absent, in these cases distinguishable by presence of rayed fins). Rayed fins always present. Breathe by gills.....CLASS PISCES

4. (1) Body not covered with scales..... 5

5. (6) Cold blooded, skin slimy.....CLASS AMPHIBIA

6. (5) Warm blooded 7

7. (8) Body covered with feathers.....CLASS AVES

8. (7) Body covered with hair.....CLASS MAMMALIA

REFERENCE

Ward, Henry B. and Whipple, George C., 1918. Fresh Water Biology. John Wiley and Sons, Inc.

Lutz, Frank E., 1921. Field Book of Insects. Revised. G. P. Putnam's Sons.

DRAGON AND DAMSEL FLY NYMPHS

(Materials: Mason jars and jar lids, carmine suspension.)

Classification:—Phylum Arthropoda, Class Insecta, Order Odonata.

Distinguish two kinds of odonate nymphs, those with slender bodies and three flat plate-like gills at the posterior end of the abdomen; and those which lack these plates and are stout bodied. The ones with the plate-like gills are called "damsel fly" nymphs and the stout bodied ones are "dragon fly" nymphs, though the name 'dragon fly' is also often used as a general term for all insects of the Order Odonata.

Keep your specimens under water. A Mason jar lid makes a convenient dish. Invert the jar and place the lid containing the specimen on the bottom of it. This brings the specimen to a convenient height for study with a hand lens.

I. Dragon Fly Nymph

1. Describe the resting habits and position of nymphs in an aquarium. Where do they usually rest? Notes required.

2. Do the nymphs ever feign death or "play possum?" If so, under what conditions? Have you ever seen this habit in other animals? What kinds? Notes required.

3. Place a large nymph in a Mason fruit jar lid. Place a small drop of carmine suspension near the posterior end of the abdomen of a resting nymph and describe the result. *Repeat the experiment until you are sure of the results.* In connection with this experiment remember that carmine is inert and is used merely to show the presence of and direction of water currents. State your observations. What conclusions may be drawn from this experiment? Notes required.

4. Describe the methods of locomotion of the live animal. How many different methods? Describe each. Notes required.

5. Note the adaptation of the labium (lower lip) for grasping food. Examine preserved specimen and with forceps draw the labium forward to fully extended position. Draw side view and dorsal view of labium, fully extended, X5.

6. Draw the entire animal, dorsal view, X4. Label the head, the thorax (the part bearing the legs), and the abdomen.

7. Into what kind of an animal does the nymph transform? See demonstration. Notes required.

8. Define metamorphosis. Notes required.

9. Consult Hertwig, p. 401, and learn how insects and aquatic insects in particular, breathe. Describe concisely in notes. See charts. Notes required.

10. The three plate-like gills of the damsel fly nymphs contain the air tubes (tracheae), while in the dragon fly nymphs the posterior part of the intestine is modified and contains tracheal filaments. Air and not blood circulates in these tubes, and aerates the tissues.

II. Damsel Fly Nymph

1. Describe the habits of the live animal, its methods of locomotion, habit of resting, etc., while in an aquarium. Describe fully. Notes required.

2. Does the animal feign death? If so, under what conditions and for how long? Notes required.

3. Draw the entire animal X4, dorsal view.

4. Draw X5, a plate-like gill.

5. Examine the expanded labium from the side and from the ventral surface. Compare with labium of dragon fly.

6. Into what kind of an animal does the nymph transform? See demonstration.

POND SNAIL

Physa or Planorbis

Classification:—Phylum Mollusca, Class Gasteropoda, Order Pulmonata.

1. Physa and Planorbis are two of the most common genera of pond snails found in this region. The two genera are readily distinguishable one from the other by the general shape of the shell, that of Physa being more or less cone shape while that of Planorbis is a practically flat coil. Indicate by labels which kind is being studied.

2. Place a snail in a Mason jar lid filled with water. Allow the snail to crawl onto the under side of a glass slide, one end of which is placed in the water. Notice that the *body* protrudes from a single opening in the *shell.* Examine a fully extended body and on its ventral surface note a crosswise fold which separates it into a small anterior region, the *head,* and a larger triangular posterior region, the *foot.* The head bears the *mouth* on its ventral surface and a pair of *tentacles* on the dorsal surface.

3. The *mantle* is a membrane which lines the shell. In fact the shell is formed by secretion from the mantle. In Physa the mantle may be seen best on the right side where it folds back upon the side of the shell in a series of small, pointed projections.

4. Both Physa and Planorbis breathe by lungs. Consequently they must come to the surface of the water occasionally for air. The *lung opening* is a small circular opening into the side of the body between the foot and the shell. It can be seen only when the snail is at the surface of the water taking air.

5. Draw X4 a side view of a fully extended snail, from the right side. Label all of the parts. Draw a ventral view X4.

6. Observe the method of feeding by looking through the side of the aquarium at the ventral side of the animal. Can you determine the nature of the food? Notes required.

7. When snails are not disturbed in what part of the aquarium do they accumulate? Notes required.

8. Describe the method of crawling. Observe a snail crawling on the lower side of the surface film of water. The lateral stretch or pull of surface tension supports the weight, just as an oiled needle may float upon the upper surface of the film. *Mucus threads* may usually be demonstrated when the animal is crawling upon the surface film by drawing a dissecting needle across the path of the animal just a short distance behind the posterior end of the body. Such threads are frequently found extending between the bottom of the aquarium and the surface film thereby providing a path along which the snails crawl back and forth.

9. Have you observed other animals moving upon the surface film? If so, what kinds? Notes required.

10. Describe the masses of snail eggs. Examine them with the microscope and describe their general appearance.

11. The growth of the shell takes place in what direction? Can you find evidence of periods of growth and rest? Notes required.

12. Observe carefully the *lung opening*, and determine by your watch how frequently and under what conditions air is taken in. RECORD IN YOUR NOTES six trials. What is the average?

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A STUDY OF THE INTERRELATIONS BETWEEN BIRDS AND FOREST VEGETATION

Materials required for trip:—Laboratory Directions, rough note paper, pencil or pen.

This study is based upon a field trip to the University of Illinois Forestry. The same outline is adaptable for a field trip to any sort of a planted grove or to fence rows where the vegetation is allowed to grow.

Rough notes are to be taken in the field. Later these are to be written up in the form of a connected report which is to be organized under the following headings:

I. Introduction.

II. Facts observed and Inferences.

III. Conclusions.

The Introduction should bring into relation all information considered necessary for an understanding of the observed facts.

A. Suggested Materials For Introduction

1. Aim of this study: An appreciation of the work of birds as agents in the distribution of vegetation and the effects of their work upon the plant and animal life of a region.

2. Before 1871 there were no trees of any sort in this plot now known as the University of Illinois Forestry. Originally there was a dense growth of grasses and low type of vegetation characteristic of the prairies but this sod was broken and the ground was put under cultivation for a considerable number of years before the first trees were planted. Since the breaking of the sod and the planting of the first trees by man in 1871 there have been many agencies at work bringing about changes in the plant and animal life of the region.

One of the important agencies in bringing in new kinds of plants has been the wind, to whose action seeds of dandelion, thistle, maples, elms and of many other kinds of plants have been introduced. Animals like dogs, horses and men have scattered the seeds of burs and other fruits which cling to the body or clothing. Squirrels and jays have buried many kinds of nuts, some of which have germinated. Birds and other animals have eaten the seeds of fruits which pass through the digestive tract uninjured. In this present study attention will be directed to the last of these agencies only.

3. Because of their greater range of movement and preference for fruit diet, birds have greater influence in distributing seeds that any other group of animals. The stomach contents of thousands of birds have been examined by experts and show that some fruits are favorite foods of many different species of birds. Thus elderberries have been found in the stomach of 67 different species of birds; raspberries and blackberries in 60 species; mulberries in 48 species; dogwood in 47 species; nonpoisonous sumachs in 44 species; wild cherries in 39 species; blueberries in 37 species; wild grapes in 29 species; pokeberries in 26 species; Virginia creeper in 25 species; juniper in 25 species; strawberries in 16 species; hackberries in 15 species; haws in 12 species; rose hips in 11 species; gooseberries and currants in 10 species.

4. Fruits are carried to nestling birds even in species the adults of which do not ordinarily eat fruits.

5. Not all seeds are capable of bird dispersal. A pulp attractive to the birds as food must be present, then if the seeds are small enough they will be swallowed along with the pulp. If the seeds are provided with hard or tough seed coats at least some will escape crushing in the gizzard and pass out along with the excrement.

6. The undergrowth of this forest is largely cut out each year.

7. Large flocks of blackbirds usually roost in this forestry in the spring and fall.

B. Outline of Field and Laboratory Study to Be Based Upon Observed Facts and Inferences

Throughout the report be careful to distinguish between actual facts that you observe and conclusion that you draw from these facts. Wherever possible give a definite statement of just what was observed then a statement of the conclusions that are drawn from these observations.

THE KINDS OF SEEDS SCATTERED

In this study it is well to distinguish between the woody plants as trees and shrubs and those which do not have a woody stem, the herbs.

1. How can you distinguish the planted vegetation from that derived from other sources? Trees, shrubs, tree seedlings, and herbs?

2. List the trees which produce fruits eaten by birds.

At demonstration table in laboratory examine fruits preserved in formalin to determine if they possess the characters essential for distribution by birds.

3. List the shrubs which produce similar fruits and examine fruits at demonstration table.

4. List the herbs in the same manner.

At least 15 plants, including trees, shrubs, and herbs, must be included in the above three lists. Aid will be given in the identification of these plants.

EVIDENCE OF THE SCATTERING OF SEEDS

1. Do you find wild cherry seedlings elsewhere than under cherry trees? Describe fully your observations, places where found, under what kinds of trees, size of seedling, etc.

2. Under what kinds of trees do you find cherry stones? List them. Can dispersal by wind explain the location of these seeds? Direction of prevailing winds?

3. Of the seeds that are scattered, do all of them grow, or, if so, to full size? Is the above absence of plants proof that the seeds have not been scattered?

4. Note bird excrement. Where found and relative abundance?

5. Do you find any evidence of the location of bird roosts? Describe fully.

C. Conclusions and Practical Applications

(a) The influence of the scattered seeds upon the forest

1. How have the introduced seeds and plants changed the character of the forest in its trees, shrubs, herbs?

2. How would the bird-introduced plants influence the present forest as a bird habitat if left uncut for a few years?

3. Do the seeds of the introduced plants germinate in open grass lands like the original prairie before the sod was broken?

4. Do the animals which now live and breed in the forestry regularly breed in open meadows?

5. What effect has the planting of the first trees had upon the *invasion* of the area by new organisms?

6. State the composition of the forest which would *succeed* the present one if left uncut. Would it be denser or less dense? Would it favor the same or different kinds of animals?

(b) Practical applications

1. What kinds of trees and shrubs should be planted if you wish to attract birds about an estate by means of bird food?

2. If you wish to protect cultivated fruits from the depredations of birds, what kinds of wild fruits should be planted to serve as food? In this connection it is necessary to keep in mind the time of ripening of the cultivated and wild fruits.

3. What injury or harm is produced by seed plantings by birds? Weeds? Poisonous plants? Choking out of cultivated plants?

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Burrill and McCluer, 1893. The Forest Tree Plantation. (Bulletin No. 26, Illinois Agricultural Experiment Station.)

McAtee, W. L., 1910. Plants Useful to Attract Birds and Protect Fruit. Yearbook U. S. Department of Agriculture for 1909. pp. 185-196.

USE OF THE MICROSCOPE

(Materials: cotton, wool, water)

I. Instructions to Be Followed in Using the Microscope.

1. Each student is responsible for the condition of the microscope with his desk number. If the microscope does not work properly at any time the fact should be reported to the instructor

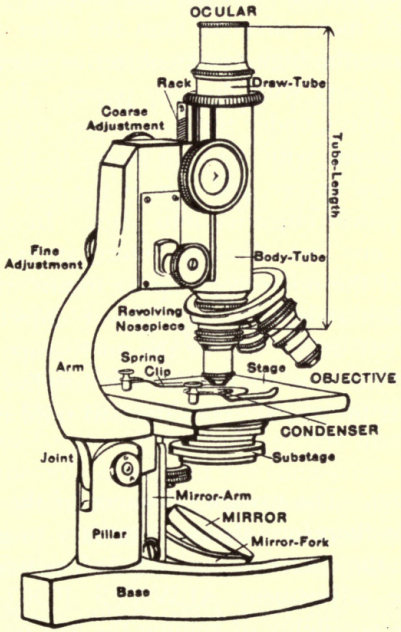

Figure 15. A Compound Microscope. From S. H. Gage, The Microscope. 1917. Comstock Publishing Co.

in charge of the laboratory section at once. The microscope is a delicate instrument and must not be handled roughly. All parts should work easily. Do not force parts at any time.

2. Before attempting to use the microscope become familiar with the names and uses of the parts. Study figure 15 carefully.

3. Proper way to carry a microscope. In carrying a microscope, it should be lifted by the arm and held in an approximately upright position to prevent the ocular from dropping out. See figure 15.

4. Lenses. The *lenses* consist of (a) the *ocular* or upper lens, (b) a *low power objective,* the shorter of the two objectives and (c) a *high power objective,* the longer of the two objectives. Before and after using see that the lenses are clean. Use lens paper for cleaning them. Do not use a cloth. The low power objective is much more effective than the other for all ordinary work. Do not use the high power objective when you can make out the desired points with the low power. In using the high power find the object under the low power first, move the part you desire to examine with the high power to the exact center of the field of the low power, and then if the lenses are "parfocal" swing the high power objective into place. In case you find the two objectives are not directly interchangeable (=parfocal draw the tube of the microscope up by means of the coarse adjustment and then swing the high power objective into place. Now with your eye at the side of the microscope on a level with the stage lower the lens until it almost touches the coverglass. With your eye at the ocular focus upward until the object comes into view.

5. Focusing. The working distance of the fine adjustment is short and it is therefore always necessary to get the approximate focus with the coarse adjustment before using the fine. In using the coarse adjustment ALWAYS FOCUS UPWARD. This relieves the possibility of ruining the lens or the slide.

6. Light. The proper adjustment of the light is essential. It is accomplished by giving the mirror the proper tilt and by changing the size of the opening in the stage. In some of the instruments there is a socalled iris diaphragm for this purpose, below the stage of the microscope. Study the operation of the mirror and of the diaphragm. Then with the eye at the ocular practice adjusting the mirror so as to secure a perfectly uniform illumination of the field of the microscope.

7. In looking through the microscope keep both eyes open. A little practice will enable you to neglect wholly the image in the unused eye and will avoid the muscular strain due to the closing of one eye. It is well to use right and left eyes alternately.

8. Keep the stage of the microscope horizontal. It is always better to adjust the height of your chair than to tilt the microscope.

9. Do not use the stage clips unless it is absolutely necessary. Turn them back so that they will not be in the way.

II. Exercise in the Use of the Microscope

1. Inversion of the image in the microscope. Place the card which has been given you upon the stage of the microscope in proper position for reading. Find a letter "e" and without shifting the position of the card draw, in outline, 40 mm. high.

2. On the slide containing mounted colored fibers determine the relative positions of the fibers by focusing up and down. Use the high power objective. In this exercise amount of color must not be confused with sharpness of focus. A dark color out of focus may strike the eye more forcibly than another color which is in the plane of focus. Distinctness of the margins or outlines of the fibers is the only safe point for comparison. In your notes indicate relative positions of the fibers beginning with the lowermost (1, 2, 3, etc.). While your slide is still on the microscope ask to have your observations verified. No drawings required.

3. Examine dry cotton fibers with low and high powers of microscope. Allow a drop of water to run under the coverglass by applying with a pipette to the slide at the edge of the coverglass. Make a drawing of the wet fiber 10 mm. in diameter, being sure to include in your drawing at least one place where the fiber is twisted. If you have studied the fiber carefully you should be able to come to a definite conclusion regarding its form as an object with three dimensions. At the side of the drawing already made place a diagram illustrating your conclusion regarding the shape of a cross-section of this fiber.

4. Place wool fibers on a clean slide. Apply coverglass and study when dry and when wet as for cotton. Examine the outline of the fiber carefully. Draw a wet fiber, 10 mm. in diameter, and construct a cross-section as directed before.

What differences do you observe between the dry and the wet fibers? Notes required.

5. Mount a drop of a Protozoan culture in such a way as to include minute air bubbles. The inclusion of cotton fibers with the drop of water will facilitate the formation of the air bubbles. Study air bubbles and Protozoa and other micro-organisms with special reference to the use of the focusing and lighting adjustments of the microscope. No drawings are required.

6. To determine the size of microscopic objects. One of the commonest means of measuring microscopic objects is by means of an OCULAR MICROMETER. The oculars for which these

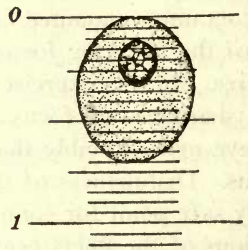

Figure 16. The use of an ocular micrometer. A cell under the low power of the microscope. Note that the cell is 14 of the smallest micrometer divisions in length. Its actual length is then; 14x0.0078 mm.=0.109 mm. Since the scale in the ocular remains the same regardless of the objective used this same cell under high power would be about 64 of the smallest micrometer divisions in length. Consequently each division would have a correspondingly smaller value.

directions are given have a scale divided by fine lines into 100 units of length. The lines appear in the field of the microscope at the same time that the object to be measured is seen. Notice that the upper portion of an ocular micrometer may be pulled out or shoved in to permit of sharp focusing upon the ruled scale. Before inserting the ocular micrometer into the tube of the mi-

croscope look through it toward the light and adjust the draw-tube until the lines and figures in the field of the ocular become most distinctly observable.

These lines are always the same distance apart regardless of the power of the *objective* used but since the size of the object to be measured varies with the objective used it become necessary to find the value of the ocular divisions for the different objectives. When used with a low power (Spencer Lens Co. 16 mm.) objective a single one of the smallest divisions of the ocular scale has the value of 0.0078 mm. With the high power (Spencer Lens Co. 4 mm.) objective each of the smallest ocular divisions has the value of 0.0017 mm.

To measure an object under the microscope find the number of smallest micrometer units in its length (or other dimension) and multiply that number by the value, as given above, of a single ocular unit for the objective you are using.

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AMOEBA

Classification: Phylum Protozoa, Class Rhizopoda, Order Lobosa.

1. Method of Examination. Upon a *clean* glass slide mount a small piece of the ooze containing Amoeba. Cover with cover glass. Note appearance under low power. From time to time add a drop of water on the slide at the margin of the cover glass to replace loss by evaporation. If a full answer can not be given at once make temporary notes, reserving the final answer until all the observations are completed.

2. General Form. Is the form constant? Is there any plane of symmetry? Anterior or posterior end? Is there a characteristic form or shape? Notes required.

3. Structures and Functions. The body layers. Study under high power. The outer clear layer is the *ectoplasm.* Structure? What part does it play in the movements of the animal? The inner granular mass is the *endoplasm.* Structure? Movement? Within the endoplasm distinguish *food vacuoles,* which are usually dark in color and may be of any shape or size, and the small *water vacuoles* which appear grey or colorless and are always perfectly spherical in form.

The blunt processes which are thrust out from time to time and retracted are *pseudopodia* (false feet). How are they formed? Do any of them branch? About how many can you count at any given time? Are they confined to any particular part of the body? Mention two functions which they perform. Describe in detail the method of locomotion in the Amoeba, telling what part the ectoplasm and the endoplasm each plays. Is there any coordination in movements? Notes required.

Make six outline sketches of your specimen at intervals of approximately twenty seconds to show the changes of form. Indicate with arrows in each drawing the direction of movement of the granules in each pseudopodium. Each drawing should be at least 40 mm. in diameter.

Note differences in number and in arrangement of pseudopodia in an Amoeba that is floating free in the water and in one that is creeping upon the surface of the slide or coverglass.

Watch an Amoeba feeding and describe the process of taking food. Watch and describe any changes in particles of food which have been engulfed. Where does digestion take place? What becomes of the food particles? Notes required.

Contractile Vacuoles. Find one or more. They are circular in outline and disappear from time to time. Note and describe carefully the method of disappearance and reappearance. Has the contractile vacuole any color? Any definite position in the body? In which body layer? Source of its contents? Nature of its contents? What becomes of the contents when a vacuole disappears? Notes required.

NUCLEUS. Find in living specimen. Describe its appearance. Does its form change? Does its position change? Is there more than one nucleus? Notes required.

Make a careful drawing 100 mm. in diameter, of the living Amoeba under the high power, labeling all parts. Stipple one pseudopodium to show structure of endoplasm and its inclusions and in addition show structure of other important parts such as nucleus and vacuoles which may not be included in this pseudopodium. In the remainder of the body indicate division between ectoplasm and endoplasm by a dotted line.

With the aid of ocular micrometer find the approximate size of an Amoeba (see page 36, section 6).

4. EXPERIMENTS. Notes required.

(1) Object: to determine the effect of a mechanical stimulus upon an Amoeba.

Clamp slide firmly to stage and gently tap the cover glass with a needle. Results?

(2) Object: to determine the effect of increased temperature upon the activity of an Amoeba.

Describe the effects of warming slightly upon movement and upon the activity of contractile vacuoles. The slide may be warmed slightly by clamping to the stage then bringing the tip of the finger in contact with the bottom of the slide through the open diaphragm.

While completing the work on Amoeba be on the lookout for specimens which are dividing and encysting. When found describe and draw.

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Greenwood, M. 1886-87. On the Digestive Process in Some Rhizopods. Part I. Jour. Physiology 7:253; Part II. Jour. Physiology 8:263.

Schaeffer, A. A. 1920. Amoeboid movement. 156 pp. Princeton University.

PARAMECIUM

(Materials: Carmine suspension, tannic acid, 15% alcohol, cotton, filter paper.)

Classification: — Phylum Protozoa, Class Ciliata, Order Holotricha.

I. Method of Examination. From an Assistant at the preparation table get a drop of water from a culture containing Paramecium. Place this on a slide with a few cotton fibers, then add a cover glass. The fibers help retard the movements of the Paramecia and thereby facilitate examination especially with the high power. Examine with low power. From an Assistant learn how to distinguish Paramecia from other Infusoria.

II. General Observations. Describe the shape. Is it constant? Is there a plane of symmetry? Anterior end? How determined? How does it differ from the posterior end? Is there a dorsal (upper) and a ventral (lower) surface? Why? Notes required. With ocular micrometer find length and breadth of a Paramecium. Make a model in clay showing the form of Paramacium.

The surface bearing the mouth is called the *oral surface.* Make an outline drawing 60 mm. long, showing oral view. The mouth should be about equidistant from the lateral margins of the body in this drawing. The surface opposite the oral surface is called the *aboral surface.*

Draw lateral view in outline, 60 mm. long.

III. Structures and Functions. 1. Cilia are delicate protoplasmic projections from the bodies of ciliates. Their detection requires a very careful adjustment of the light through the microscope. Are they evenly distributed? Note the arrangement of individual cilia as far as possible. Of uniform size? Do all move? What functions do the cilia perform? Compare Amoeba

and Paramecium with reference to locomotion. Notes required.

2. The body of a Paramecium consists of three distinct parts; (a) a thin, non-living, external covering, or cell wall, the *pellicle*, (b) a thicker, fixed layer, the *ectoplasm*, in which the *trichocysts* are embedded, and (c) the more fluid, granular, inner mass, the *endoplasm*.

3. To demonstrate the *trichocysts* run a little tannic acid under the cover glass. This kills the animals upon contact, but in so doing the trichocysts are shot out from the body. Describe the effect the instant the tannic acid reaches an animal. Draw (60 mm. long). Thoroughly wash off your slide and cover glass and get a fresh preparation. Use high power on living specimens and look for the *trichocyst layer* in the ectoplasm. Notes required.

4. To demonstrate the *pellicle* run a little fifteen percent. alcohol under the cover glass. Notice how the pellicle becomes separated from the ectoplasm. Explain the markings seen on the pellicle with high power. Draw (60 mm. long.) Notes required.

5. To observe the *endoplasm* and its movements get a fresh preparation and before applying the coverglass add a little carmine suspension to the water containing the Paramecia. The carmine is added here for use in a later part of the work. Carmine particles, while of no food value, are taken into the body along with food, thus by their color making the food vacuoles very conspicuous.

6. How does the endoplasm differ from the ectoplasm? Are the two entirely distinct? Watch specimens crowd through narrow places. How are ectoplasm and endoplasm affected? Notes required.

7. Under high power watch the passage of carmine grains down the *gullet*. Describe the formation into food vacuoles. Where do they enter the endoplasm? Do they move in a definite direction? Compare motion with that of granules of endoplasm. Notes required.

8. Note the streaming of granules in the endoplasm. Direction? Distinguish the spherical *food* and *water vacuoles,* the minute *structural granules* of the endoplasm, and the small *crystals.*

9. Describe the course of the *oral groove.* On what surface of the animal is it located? The groove continues at its posterior end into the *gullet.* Describe the course of the gullet. Is it lined with cilia?

Solid waste material which accumulates in the body is discharged through a special opening called the *anus.* Ordinarily this is not observable except when waste matter is being given off. There was neither mouth nor anus in Amoeba. Why are they necessary in Paramecium? Notes required.

10. CONTRACTILE VACUOLES. How many? Position? Is it definite? In which body layer? *Radiating canals.* When best seen? How many? Do they always communicate with the contractile vacuoles? How are vacuoles filled? How and where do they empty? Best determined by examination from right or left side. Accurately time 5 pulsations. Warm and time. Notes or table required.

11. NUCLEI. Division of labor is accompnaied by a specialization of the nuclear material in the Ciliates. Instead of a single nuclear mass there are two nuclei in each cell. The larger of these, called the *macronucleus,* seems to have control of the ordinary bodily functions, while the *micronucleus* is concerned chiefly in the reproductive process. These nuclei are not observable in the living animal. At the demonstration table examine stained specimens. By use of the ocular micrometer measure the length of the entire animal, the macronucleus, and micronucleus. Use these measurements to insure correct proportions in drawing asked for in next paragraph.

12. Make a large drawing, 150 mm. long, of a living Paramecium, side view, locating and labeling various structures. Show structure carefully in part of drawing 1 cm. back from the anterior end of the body. In remainder of body show division be-

tween ectoplasm and endoplasm by dotted line. Nuclei seen in stained demonstrations should be shown in this drawing. Indicate direction of protoplasmic currents by a series of arrows showing course through the entire cell.

13. REPRODUCTION by simple transverse fission. If possible watch and sketch the process in living specimens. Time for process of fission? How many mouths just before fission is completed? How many contractile vacuoles? Are the two resulting individuals alike? See stained demonstrations.

14. Look for pairs of Paramecia undergoing *conjugation.* See demonstrations.

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Minchin, E. A., 1912. An introduction to the study of the Protozoa. Arnold, London.

VORTICELLA

Classification:—Phylum Protozoa, Class Ciliata, Order Peritricha.

Make out: (1) Shape. Is it constant? (2) *Cilia.* Distribution and functions? Does Vorticella ever swim about? (3) *Groove, mouth,* and *gullet.* (4) *Ectoplasm* and *endoplasm.* (5) *Food vacuoles.* (6) *Protoplasmic granules.* (7) *Contractile vacuoles.* (8) *Macronucleus.* (9) Structure of *stalk.* (10) Reproduction. (11) Make a large drawing, 50 mm. across, showing the parts you have seen. With ocular micrometer determine the diameter of the bell.

EUGLENA

(Materials: filter paper, aqueous iodine)

Classification:—Phylum Protozoa, Class Flagellata, Order Autoflagellata.

Make out:—(1) Shape. Is it constant? Compare locomotion with that of Amoeba and Paramecium. (2) *Flagellum,* attachment? Function? A drop of aqueous iodine applied before the coverglass is put in place stains the flagellum on many specimens so it may be seen readily. Since the iodine kills the Euglena a new preparation must be secured for the remainder of the study. (3) *Mouth* and *gullet.* Relations to flagellum? (4) *Ectoplasm* and *endoplasm.* (5) *Red eyespot.* (6) *Reservoir of the contractile vacuoles.* (7) Green bodies, the *chromatophores,* containing chlorophyll. (8) The *nucleus,* near the middle of the body. (9) Occasionally small rounded masses, the *paramylum bodies,* are found. These are a form of stored animal starch and resemble starch grains.

Make a drawing, 120 mm. long, showing the parts you have seen.

With an ocular micrometer find length and width of a Euglena.

Though the Euglena possesses a mouth and gullet no one has ever seen it take solid food particles. In its metabolism it is distinctly plant like. Through the energy of sunlight the chlorophyll bodies combine carbon-dioxide and water to form starch which is used as food.

Euglena reproduces by *longitudinal fission* which begins at the anterior end. The old flagellum is retained by one half while the other half produces a new one.

COLONIAL PROTOZOA

Among the Protozoa are found some forms in which the individual cells do not separate immediately after fission but remain attached to form either temporary or permanent groups of cells called colonies. The chief point wherein these protozoon colonies differ from true many-celled animals, the Metazoa, lies in the fact that while certain cells may be set aside and specialized for *reproduction* all the other cells of the body, the *somatic cells*, remain similar one to another, i. e. they lack *histological differentiation.*

Pandorina and Eudorina are two examples of such colonies consisting of a small number of similar cells held together by a jelly-like substance called the *matrix.* In reproduction each cell of the colony may continue to divide by simple fission until it forms a new colony. This is the *asexual* method of *reproduction.* Some of the colonies may produce *male sex cells* and others *female sex cells.* In these cases a male sex cell must unite with a female sex cell to form a single cell called a *zygote* which is the starting point of a new colony. This is the beginning of true *sexual reproduction.*

Observe under demonstration microscope stained mounts of Eudorina and Pandorina. Then as you take up the study of Volvox note how these serve as a transition from the forms with no colonial tendencies, such as Paramecium and Euglena, to the more highly specialized condition found in Volvox.

VOLVOX

Classification:—Phylum Protozoa, Class Flagellata, Order Autoflagellata.

Read the entire Volvox outline before beginning to study the prepared slide.

In Volvox is found a still higher type of colony life where several hundred or even thousands of cells have become associated to form a single layer of cells over the surface of a sphere. In such a colony some individual cells are commonly specialized to carry on the reproductive function while all of the remaining cells (somatic cells) are similar. These colonies live in ponds and pools where they swim about freely by the action of the flagella with which the somatic cells are provided, progressing with a smooth rolling motion. Ordinarily in preserved material used for study these flagella are not distinguishable.

There are a number of different species of Volvox. These differ among themselves in details of structure as well as in methods of reproduction. The material selected for this study belongs to the species *Volvox weismannia.* In this species there are two different methods of reproduction involving three different types of individuals. The simplest and most characteristic method of reproduction is found in the *parthenogenetic female colonies.* In these, some of the cells become set apart as reproductive cells and are called *parthenogenetic macrogametes,* arising in the colony wall, they increase in size until they are shoved into the interior of the colony. Macrogametes of this sort are capable of undergoing development directly without being fertilized. Each gamete by repeated divisions forms a group of cells which become arranged as a small sphere within the parent colony. Only by rupture or disintegration of the wall of the parent colony are these young colonies liberated. This method of *parthenogenetic reproduction* continues as long as conditions are favorable.

At certain times the young colonies instead of producing parthenogenetic gametes develop into true sexual individuals. Thus there are formed *male colonies* which develop only *microgametes* or male cells and *sexual female colonies* which produce only *sexual macrogametes.* In these true sexual individuals neither type of the reproductive cells is capable of undergoing reproduction independently, for fertilization is necessary. When fully formed the microgametes leave the male colony and penetrate the wall of the female colony. When a microgamete unites

with a sexual macrogamete within a female colony a fertilized egg called a *zygote* is formed. The zygotes thus formed do not undergo development immediately but each becomes encased in a firm, resistant membrane. When a female colony bearing these protected zygotes disintegrate the zygotes fall to the bottom of the pond and remain there inactive for some time. With the return of favorable conditions for development each zygote loses its protective shell and undergoes cell division to form a new colony.

Examine Volvox colonies with a microscope. Use high power and focus very carefully with the fine adjustment, at first directing attention to the *surface* of the colonies and ignoring the large, more deeply stained masses deeply imbedded within the colony. The small darkly stained spots rather uniformly arranged in the wall of the sphere are the *somatic cells*. The less deeply stained material between these cells in the *matrix*. Make a drawing of a small portion of the colony wall showing the relation of cells and matrix.

At demonstration table examine specially prepared slide of Volvox showing the fine *protoplasmic threads* which pass through the matrix connecting each somatic cell with the adjoining cells. Draw a small portion, greatly enlarged.

In this species the relative numbers of somatic cells in the wall of the colony is one of the easiest means of distinguishing the two sexes. Find a colony in which the distance between two adjacent somatic cells is more than twice the diameter of a single somatic cell. This is a male colony. Because of the wide separation of the somatic cells such a colony appears much lighter in color than the other colonies. The darkly stained masses on the interior of a male colony are *clusters of microgametes*. By careful focusing the shape of the single microgametes within a cluster may be determined. Note that clusters of microgametes near the equator of the sphere are shown in side view.

Make a drawing, 60 mm. in diameter, showing a male colony in optical section. In such a drawing only a single ring of so-

matic cells should be shown but all of the clusters of microgametes should be drawn in outline. Detailed structure of at least one cluster of microgametes should be brought out.

The two kinds of female colonies are much alike in structure. In them, the distance between two somatic cells is usually not more than the diameter of a single somatic cell. There is no reliable constant difference in the appearance of either the somatic cells or of the macrogametes in the parthenogenetic female colonies and the true sexual female colonies. Observations upon living material have demonstrated that the chief difference lies in the number of gametes. True *sexual female colonies* of this species contain sixteen or more gametes while female colonies containing twelve or fewer macrogametes are *parthenogenetic female colonies.*

Make a drawing of each kind of female colony showing colony wall in optical section and showing in outline the total number of macrogametes characteristic of each. Show at least one macrogamete in detail.

See demonstration of *zygote* and draw, about 20 mm. in diameter.

MITOSIS

Reproduction of the Cell

All living organisms are built up of minute units called *cells.* The power of an organism to reproduce itself is dependent upon the ability of these protoplasmic units to divide and thereby reproduce other cells. *Mitosis* is the name applied to the long series of intricately correlated changes which the *nucleus* undergoes during the division of the cell. Cell division is especially active and conspicuous in the early development of an individual from a fertilized egg. The structures involved in mitosis are so minute that they can not be studied easily in entire cells, consequently cells undergoing mitosis are preserved and cut into thin slices (*sections*) by the use of an instrument called the microtome.

These sections are then treated with *stains* or dyes. Various parts within the cell react differently to the stain and for that reason are easily distinguishable. *Chromatin*, one of the materials within the nucleus, is especially deeply colored by the stains most frequently used.

In interpreting sections of cells in this study keep the following facts in mind:

1. The nucleus is much smaller than the entire cell, consequently many slices through a given cell will contain no part of the nucleus.

2. Before mitosis has begun the nucleus is very conspicuous as a large light colored body in which some darker granules of chromatin are found.

3. Early in the process of mitosis the membrane surrounding the nucleus disappears, allowing the nuclear material to lie directly in the protoplasm. From this time there is no sharply defined light colored body to represent the nucleus.

4. The *spindle* formed by the *centrosome* has but one chief axis. The developing eggs are too small to be placed all in a uniform position, consequently when sections are cut only part of them will pass through the spindle and of these only a very small percentage will contain the entire spindle. Most of the sections passing through the spindle will cut it at various angles to its chief axis and will thus include only a portion of the mitotic figure.

In *sections* of the eggs and embryos of Cerebratulus or in sections of the spermary of the Salamander study the following stages in the process of mitosis and make one or more drawings of each. Divide the page into six parts and place drawings in proper order as the different stages are found.

For the resting stage draw the entire cell. In the remaining stages draw the nuclear structures and mitotic figure only.

1. Resting Stage. Chromatin scattered throughout the nucleus in the form of small granules.

2. Prophase. Chromatin becoming arranged in masses, usually forming a coiled thread, the *spireme*.

3. Metaphase. The chromatin thread has broken into *chromosomes* which have become arranged in the *equatorial plate*. In this stage each chomosome has split longitudinally but because of their minute size in Cerebratulus the individual chomosomes are not readily observable.

4. Anaphase. Chromosomes moving toward each pole of the spindle.

5. Telophase. The construction of the two *daughter nuclei*. This is usually accompanied by a *cleavage* of the cell, whereby the two daughter nuclei become the nuclei of two *daughter cells*.

REFERENCE

Wilson, E. B., 1900. The Cell in Development and Inheritance. MacMillan.

EMBRYOLOGY OF CEREBRATULUS

Classification:—Phylum Plathelminthes, Class Nemertini, Order Heteronemertini.

Cerebratulus is a marine worm which lives in burrows on sandy beaches. Its reproduction is by the sexual method. When the females reach maturity they discharge enormous numbers of *eggs* into the surrounding water. At the same time the males discharge myriads of small, motile *spermatozoa* into the water. These spermatozoa, through their powers of locomotion, come into contact with the eggs liberated by the females. Under nor-

mal circumstances but a single sperm cell enters each egg cell. Before the union of the nuclei of these germ cells each of the uniting cells has undergone a series of preparatory changes called *maturation.* The fusion of the two germ cells to form a single cell with a single nucleus constitutes the act of *fertilization.* From the egg thus fertilized a new individual is formed. The early stages in this development will be studied in prepared slides of preserved eggs and embryos.

You will be given slides in which numerous eggs and embryos in various stages of development are mounted in a drop of balsam. THESE MOUNTS ARE VERY FRAGILE AND SHOULD BE HANDLED WITH THE UTMOST CARE. Even in wiping the dust from the coverglass be very careful that no pressure is brought to bear upon the coverglass.

In this exercise be sure to place the drawings in order on the page. Make six drawings to the page, each one 50 mm. in diameter. Be sure to carry the same relative proportion throughout the entire series of drawings.

1. THE IMMATURE EGG may be distinguished because of its very large, light colored nucleus. A small, deeply stained spherical body, the *nucleolus,* is usually conspicuous within the nucleus. Draw immature egg. With ocular micrometer find diameter of immature egg and record next to drawing.

ORIENTATION OF THE EGG. In Cerebratulus the polar bodies are given off at the point directly opposite the original point of attachment of the egg in the ovary. The place where the polar bodies are given off is called the *'animal pole,'* while the opposite pole is called the *'vegetative pole.'* The line passing from one pole, through the nucleus and then through the other pole, is called the *'axis'* of the egg. Any line on the surface of the egg (or of the embryo) running from pole to pole is called a *'meridional line,'* while any plane including a meridian is called a *'meridional plane.'* Any plane cutting the axis of the egg (or of the embryo) at right angles is called an *'equatorial plane.'*

The polar bodies of Cerebratulus always occur inside of the outer membrane of the egg. The egg is always slightly flattened at the point where they appear.

2. Maturation of the Egg. The process through which the amount of chromatin is reduced by the extrusion of the two polar bodies is called *'maturation.'* Make at least two drawings.

3. Fertilization. After maturation the *sperm nucleus,* which had entered the egg previously, fuses with the *nucleus of the mature egg* to produce the *first cleavage nucleus.* See demonstration microscope.

4. First Cleavage. By the process of mitosis the nucleus divides. In the cleavage of the cell which accompanies this in Cerebratulus three processes may be made out; (a) the cell elongates slightly and begins to constrict, (b) the constriction entirely separates the two daughter cells, leaving but a slight contact surface between them, (c) the two cells become pushed together, forming a broad contact surface one with the other. Illustrate these points in drawings. (At least three drawings.) Observe immature egg and first cleavage stage in same low power field and compare sizes.

5. Second Cleavage. In succeeding cleavages each cell undergoes the same stages outlined in the preceding paragraph. Make three drawings to show these stages in the second cleavage.

6. Third Cleavage. (A polar and a lateral view.) In this stage note that the four cells at the animal pole are not directly above the four cells of the vegetative pole. This shifting of the position of the cells indicates what is called the 'spiral type of cleavage.'

7. Fourth Cleavage. (Polar view.) By focusing note that a cavity is already beginning to form in the center of the mass of cells. In Cerebratulus there is no morula stage.

8. Blastula Stage. Draw in optical section showing the cavity which is surrounded by a single layer of cells.

9. Gastrula Stage. In optical section show relative thickness of *ectoderm* and of *entoderm*. Measure diameter and compare with that of immature egg.

10. Write a connected account of early development in Cerebratulus, bringing into relationship the processes of maturation, fertilization, mitosis, and cleavage. In describing the first cleavage give in full an account of the process of mitosis as it occurs.

During the gastrula stage the Cerebratulus is a free-living animal. By further development the gastrula becomes modified to form a small larva known as a *pilidium*. The mature worm, several feet in length, results from the further growth and complicated transformation of this larva.

REFERENCE

Wilson, E. B., 1903. Experiments on Cleavage and Localization in the Nemertine-egg. Arch. Entw.-mech. 16:411-460.

HYDRA

(Materials: thread, filter paper, methylen blue.)

Classification:—Phylum Coelenterata, Class Hydrozoa, Order Hydraria.

1. Living Hydra. A living specimen will be given you in a watch glass with a small amount of water. Examine with dissecting lens while still in the watch glass, using care in handling the specimen to prevent injuring it.

2. General Study. Note: (1) *Body*, size and form. Does the form change? (2) The *foot* or part by which it becomes attached. How do you infer that attachment is effected? See demonstration of longitudinal section through foot. Also examine living specimens clinging to sides of an aquarium. (3) The *tentacles*. How many? Where situated? Change of form? (4)

The *hypostome*, part included between the tentacles. Form? (5) Position of *mouth?* Is the body hollow? Draw when well extended and when contracted. The extended drawing should be at least 200 mm. long, and the other in proportion.

With a pipette transfer the Hydra to a drop of water on a slide. Place two pieces of thread in the water so that when the coverglass is added they will be at two opposite sides of the coverglass for support. Study *ectoderm and entoderm.*

Study tentacles. Note small round bodies, the nettling cells. How many sizes? Are they arranged in any definite order? The short hair-like projections seen on the margin of the tentacle are the *cnidocils* mentioned under (b) on the next page. Make outline drawings to show differences in tentacles when extended and when contracted, being sure to indicate correct location of nettling cells.

3. Experiment. Run a little methylen blue under the coverglass. This acts as a chemical stimulus, causing the nematocysts to be shot out and at the same time stains them blue. If threads are not shot out from the surface of the body upon contact with the stain, tap lightly with a dissecting needle upon the coverglass immediately above the Hydra. Make out at least two kinds of nematocysts. Draw an 'exploded' specimen of each. The sac of the larger should be 10 mm. in diameter. In the exploded condition the nettling cells have been completely separated from the body so that they may be seen to consist of a long thread-like tube, one end of which is attached to a small sac-like structure, the *nematocyst.* Often some of the nematocysts which are discharged from the body are more deeply stained and more irregular in outline than the others. Such a nematocyst is surrounded by its *cnidoblast,* the cell which forms the nematocyst (see next page, section b).

4. Transverse Section. A. Low Power. Examine transverse sections and see the outer, cellular *ectoderm,* the very thin middle non-cellular layer or *mesoglea,* and the inner cellular *entoderm.* Note the general appearance and the relative thickness

of these layers. Make a diagram showing the arrangement of the body layers, 60 mm. in diameter. Cell boundaries should be shown in about one-fifth the circumference. Details of structure will be shown in another drawing called for later.

B. High Power. Study a transverse section under high power.

(a) Examine cells of the ectoderm carefully. Note that the protoplasm does not fill the entire cell but usually surrounds a more or less conspicuous open space called a *vacuole*. With a little practice the *nuclei* of these cells may be readily distinguished from the nettling cells and other bodies lying in the protoplasm. Because the cells which cover the surface of the body of the Hydra have become partially specialized for movement they are called *epithelio-muscular* cells. In transverse sections that have been specially prepared note that each of these ectoderm cells shows a row of dark dots close to the margin which lies next to the mesoglea. These are *muscle threads* cut in cross section.

(b) The *nettling cells* or *cnidoblasts* are peculiar in that they are included within the protoplasm of the epithelio-muscular cells. The *nematocyst* may be distinguished as a clear bladder-like structure which frequently encloses a solid elongated body. This last named structure is the series of barbs which become evident on one type of nettling cells when they are discharged. A small nucleus is often present just outside the wall of the nematocyst. This nucleus with the protoplasm immediately around the nematocyst constitutes the *cnidoblast*, or cell which produces the nematocyst. In a nettling cell which lies at the outermost surface of the ectoderm a small pointed projection called the *cnidocil* is frequently observable extending beyond the general surface of the body. The cnidocil used to be called the "trigger" on the supposition that it controlled the explosion of the nematocyst.

(c) Small wedge-shaped cells called *interstitial cells* are frequently found between the bases of the *epithelio-muscular*

cells. It is from these cells that the nettling cells are formed. When fully formed the nettling cells migrate through the protoplasm of the epithelio-muscular cells until they come to lie at the surface of the body where they are in a position to function.

(d) The *entoderm cells* are much larger than ectoderm cells. The protoplasm of these cells is usually filled with rounded masses of stored food material which has been taken directly from the coelenteric cavity. These masses are frequently so numerous as to obscure the nucleus.

Make a drawing of a part of the wall of the body as seen under high power. Individual cells must be at least three or four times as large as in the low power drawing. Show the structure very carefully in one or two cells of each kind.

In your 200 mm. drawing of the entire animal show in outline the location and distribution of *coelenteric cavity, ectoderm,* and *entoderm.*

OBELIA

Classification:—Phylum Coelenterata, Class Hydrozoa, Order Campanulariae-Leptomedusae.

1. Obelia is a marine colonial coelenterate which becomes attached to seaweed, piles, or other submerged objects. Study prepared slide (or a piece of a colony on seaweed). Each individual of the colony is called a *hydranth* or *zooid.* Is there any regularity in the arrangement of the zooids upon the upright branches? Each branch usually represents but a part of a colony. Several such branches may be united by a continuous root-like *hydrorhiza* which is the part by means of which attachment is secured.

2. Make a simple *diagram,* using single lines to show the arrangement of the parts of a colony. Structure is called for in another drawing.

3. Study specimen mounted on a slide and under low power compare the structure of an individual zooid with the structure of Hydra. Note, in addition to what was found in Hydra, a tough, membranous sheath, the *perisarc,* covering the surface of the colony. The vase-like expansion of the perisarc around each zooid is called the *hydrotheca.*

4. Do you notice any modifications of the perisarc below the hydrotheca? Do these serve any purpose? Notes required.

5. The fleshy continuation of the zooid down into the stalk is termed the *coenosarc.* Is it in close contact with the perisarc?

6. In an expanded hydranth, note the *mouth,* the arrangement of the *tentacles* and the number of tentacles. The mouth opens into the *coelenteric cavity* as in the Hydra. This cavity continues down through the coenosarc so the coelenteric cavities of all of the individuals of a colony are directly continuous with each other.

7. Examine hydranth and stalk with low power and look for the cell-layers which you discovered in the study of Hydra. Draw a hydranth and part of the stalk as seen under the *high* power, making the hydrotheca 80 mm. long. Cell boundaries but not cytoplasmic contents should be shown in this drawing. In your study of the hydranth you have noticed that the tentacles are very densely grouped around the mouth. In this drawing omit the tentacles from the front side of the hydranth, showing only where they are attached to the body by drawing only the bases of the tentacles across the front of the hydranth.

8. Find *reproductive individuals* and draw. These are large sack-like structures containing numerous *buds* formed asexually. These buds when fully developed, become small, free-swimming, jellyfish (see demonstration microscope) which reproduce sexually. The fertilized egg develops not into another jellyfish, but into a hydroid such as you have been studying. This condition where the offspring is not like the parent but like the grandparent, is termed *metagenesis* or alternation of generations. The hydroids produce jellyfish; jellyfish produce hydroids, etc.

9. Examine demonstrations of undeveloped hydranths. These must not be confused with old or injured hydranths which have lost their tentacles. An undeveloped hydranth is a bud, the free end of which is covered by a continuous layer of the perisarc.

GONIONEMUS

Classification:—Phylum Coelenterata, Class Hydrozoa, Order Campanulariae-Leptomedusae.

Gonionemus is the *medusoid* or jellyfish form of a coelenterate. In fundamental structure it closely resembles the medusa of Obelia and is given as a type of medusoid instead of the medusa of Obedlia because of its greater size which makes it more easily studied. The following study is to be made upon a specimen preserved in formalin:

1. The convex face is called the *ex-umbrella* (aboral surface) and the concave portion the *sub-umbrella* (oral surface).

2. The velum is a membrane on the oral surface which extends from the margin of the body inward toward the center, partially enclosing the subumbrella. In many specimens that have been handled roughly this membrane may be torn. Normally it is perforated by a single circular opening in the center.

3. Hanging in the center of the sub-umbrella is seen the *manubrium,* at the extremity of which is the wide-lipped *mouth.*

4. From the stomach, at the base of the manubrium, the four *radiating chymiferous tubes* lead to the periphery of the disc where they open into the very delicate *circumferential canal.* What is the use of these canals? Study canals in specimen with ex-umbrella uppermost.

5. The *gonads* hang in folds from beneath the chymiferous tubes into the sub-umbrella space. The eggs or spermatozoa are discharged from these directly into the water.

6. Examine the *tentacles*. How are the *nematocysts* arranged on them? Note the *sucking disc* some distance from the end of each tentacle.

7. Two kinds of sense organs can be made out on the edge of the medusa. See demonstration of:

(a) *Light-percipient organs.* These are large, round, pigmented bodies at the bases of the tentacles.

(b) *Otocysts* are small, transparent, ovoid bodies located between the tentacles. In Gonionemus each otocyst consists of a large vesicle surrounding the true sensory organ which is located at the end of a short stalk extending into this vesicle. The rounded structure at the end of the stalk contains a cavity, the *secondary vesicle,* within which a small calcareous body called the *otolith* is located.

8. Make a drawing (a) from the oral surface, 70 mm. (without tentacles), filling in outline one complete tentacle and bases of one-third of remaining tentacles, (b) of an optical vertical section through the radial tubes, (c) a portion of a tentacle much enlarged, showing sucking disc, (d) an otocyst much enlarged.

9. Make a brief word diagram showing in a circle the life history of a hydrozoan.

REFERENCES

Perkins, H. F., 1903. The Development of Gonionemus murbachii. Proc. Acad. Nat. Sci. Phila. 54:750-790.

Thomas, L. J., 1921. Morphology and orientation of the otocysts of Gonionemus. Biol. Bull., 40:287-296.

REGENERATION IN PLANARIA

(Materials: large pipette, watch glasses, pond or cistern water.)

Classification:—Phylum Plathelminthes, Class Turbellaria, Order Tricladidea.

A fresh-water flat worm will be given you in a watch glass containing pond water. Make out the characteristics of structure and movement.

Make a 100 mm. drawing across the top of a page showing as many of the following parts as possible: (1) general body shape, (2) the *pharnyx* is a cylindrical structure near the middle of the body (usually the pharnyx is retracted within the body except when food is being taken); (3) the *mouth* is at the posterior free end of the pharnyx, (4) the *intestine* consists of three main branches leading off from the anterior end of the pharnyx, (5) the *eye spots,* (6) the *sensory lobes,* earlike structures on the sides of the head.

The worm is to be cut into three pieces of as nearly equal size as possible. One transverse cut is to be in front of and the other behind the pharnyx. Sharpen scalpel on knife stone. While the worm is crawling along on the bottom of the watch-glass place the point of the scalpel against the bottom of the dish at one side of the worm. With a fairly quick rocking movement roll the edge of the knife across the body of the worm, thus severing the body with one clean cut.

On your first drawing indicate with broken lines the planes of the cuts. Make outline drawings of the three parts immediately beneath the drawing of the entire animal, placing the parts in the same relative positions. Next to these drawings record the date of the operation.

See that the watch glass is carefully covered. Change the water at each laboratory period. Make observations on structure and movements of each piece until regeneration is completed. Make outline drawings of each piece as often as directed at the beginning of each laboratory period before taking up the advanced work of the day. Record the date of each set of drawings.

After this experiment is completed write a connected account of regeneration as it occurs in Planaria.

REFERENCE

Morgan, T. H., 1901. Regeneration. MacMillan Co.

EARTHWORM

(Lumbricus terrestris)

(Materials: tags, pins, jars with formalin and covers, pipettes.)

Classification:—Phylum Coelhelminthes, Class Annelida, Order Oligochaetae.

There are numerous species and genera of earthworms. The one chosen for this study is not a native of this country but was introduced from Europe and has become established in some localities. The small worms which are found in the soil and on walks after heavy rains are usually not the young of this same species but represent a number of separate genera and species differing considerably in internal structure. Information given in this outline does not apply to all earthworms.

I. External Characters

1. Note that the body is composed of a series of similar rings placed end to end. Each of these divisions or rings is called a *somite* or *segment*. Notice that the body is almost cyl-

indrical in form but is slightly flattened on one surface. This flattened surface, which is also usually light in color, is the ventral surface of the worm. The anterior region is the more robust of the two body extremities.

2. The most anterior part, the *prostomium,* is not a true segment. How far does it extend through the next division, the *peristomium,* or first true somite? Make a drawing, X5, of the dorsal view to show the relation of these two parts.

3. The *clitellum* consists of several thickened segments forming a partial ring in the anterior region of the body. On which surface of the body is this ring incomplete in this species? Record on the drawing asked for under paragraph 10, the number of segments anterior to the clitellum, in the clitellum, and posterior to the clitellum. What part of body has a constant number of segments? Record the results of your counting after your desk number on the table outlined upon the blackboard.

4. Locate the *mouth* on the ventral surface just behind the prostomium.

5. The *anus* occurs in the last segment. Shape? Position?

6. Find the *spermiducal pores* on segment XV. Position and appearance?

7. The *oviducal pores* occur in similar positions on segment XIV, but are much smaller and visible only upon careful examination with a lens.

8. *Dorsal pores,* very small, on dorsal median line at anterior margin of each segment. Many are indistinct.

9. Find the *setae* or short bristle extending beyond the surface of the body wall. How many on a somite and how arranged? In what direction do they point? This can be determined by pulling the worm gently between the fingers.

10. Make an outline drawing X3, of the anterior part of the body as seen from the side, slightly tilted so that part of the ven-

tral surface is included, showing the somites, setae, clitellum, and reproductive pores. Number each segment.

II. Internal Anatomy

The method of opening the body wall will be demonstrated to small groups in the laboratory. In dissecting the earthworm it is necessary to split open the body wall so it may be pinned out flat, thus revealing the internal organs. In the region just behind the clitellum insert one point of the dissecting scissors and cut forward along the mid-dorsal line of the body to about the second segment. While making this cut hold the one point of the scissors just inside the body wall stationary, moving only the free blade of the scissors. This will avoid injury to the internal organs.

Note that the space inside the body wall is divided into small chambers by partitions called *septa*. With what do these septa correspond externally? Hold the worm in your left hand and with a dissecting needle note that these septa break away fairly readily. With the needle pressing outward from the cut against the body wall run it along the body until the septa have been broken along both sides of the body. Now with pins open the body wall out flat against the wax in the bottom of a dissecting pan, allowing the heads of the pins to point away from the body of the worm at a broad angle so as to be out of the way during later dissection and examination.

CIRCULATORY SYSTEM

1. The *dorsal vessel* may be seen as a small dark tube which runs along the dorsal surface of the digestive tube. How far forward does it extend?

2. Large lateral branches, *"hearts,"* pass around esophagus. Find at least four pairs. Draw a pair in optical vertical section to show their shape.

3. At demonstration table examine a piece cut through the body in the region of the hearts to see connection with *ventral vessel.*

4. *Parietal vessels* may be found in the body wall and in the wall of the intestine.

5. Make a diagram of the main trunks of the circulatory system. *Number the body segments shown.*

REPRODUTIVE SYSTEM

In studying this system be careful to prevent injury to the organs of other systems.

A. Male Reproductive Organs

1. Three pairs of *sperm sacs,* large white sacs at sides of and above esophagus. Some of them may not be very large because the specimens were not at the height of sexual activity when killed. Three pairs, in which somites? They contain *spermatozoa.*

2. Ventrally the sperm sacs are connected by a common *seminal vesicle.*

3. The *testes,* two pairs in X and XI, in positions corresponding to those of the ovaries in XIII, are small and being enclosed in the *seminal vesicle* they cannot be seen.

B. Female Reproductive Organs.

1. The *ovaries* are attached to the anterior septum of XIII near the mid-ventral line. They are generally difficult to find.

2. *Oviducal funnels* are on posterior septum of XIII opposite the ovaries.

3. The *oviducts* lead from them backwards to the ventral wall of XIV.

4. *Spermathecae,* two pairs of small globular sacs lying close to the septa between IX and X, and X and XI. They open to exterior on ventral side and receive spermatozoa from another worm.

Make a diagram of a side view showing the location of the reproductive organs found. Number segments.

C. Reproduction in the Earthworm

Because the earthworm has the reproductive organs of both sexes functional in the same individual it is said to be *hermaphroditic*. During the breeding season earthworms come out of their burrows at night for the purpose of copulation. Two individuals come together with their heads pointing in opposite directions. While in this position a mucus tube is secreted which holds the two worms with their ventral surfaces together. This brings the spermiducal pores of each in contact with the openings of the spermathecae of the other. In this manner the spermathecae of each worm become filled with sperm cells which have been produced by the other individual. This completes the act of copulation and the two worms separate.

Glands in the clitellum secrete a cocoon which is gradually worked off toward the anterior end of the worm. As this cocoon passes over segment XIV eggs are discharged into it. In the region of segments XI and X sperm cells are discharged into the same cocoon and fertilize the eggs. These sperm cells are the ones that were deposited in the spermatheca by an entirely diffrent individual during copulation. The cocoons are left in moist places where the eggs undergo development, giving rise to minute immature worms which break through the wall of the cocoon.

DIGESTIVE SYSTEM

1. In all of this work remember that the septa may be crowded either forward or backward by some of the organs. For this reason it is necessary to observe in what *cavities* the organs lie rather than observe the external body markings of segments in the region occupied by the organs. If a structure occupies more than one segment, the places where the septa crossed it are fairly easily recognized.

2. The alimentary tract, a straight tube extending through the body, has the following parts arranged in order from anterior to posterior extremities:

(a) *Buccal cavity* or *mouth cavity,* a thin walled sac-shaped structure communicating with the outside through the mouth.

(b) *Pharynx,* thick walled region with muscles running to the body wall.

(c) *Esophagus,* slender and extending through a number of somites, mostly hidden by the sperm sacs which may now be removed by picking away the pieces carefully with a pair of fine pointed forceps. The *calciferous glands* occur on the sides of the esophagus as small lobular structures. See demonstration dissection.

(d) *Crop,* an enlarged thin-walled sac. With the point of a needle note the difference in resistance of this and the gizzard.

(e) *Gizzard,* thick-walled, muscular grinding organ.

(f) *Intestine,* a tube of practically uniform diameter extending through the remainder of the body. A layer of brown cells, the *chloragogue cells,* covers the intestine. These are supposed to be associated with the excretory function.

3. Make a slit in one side of the intestine and fold back the dorsal half for the distance of about 10 mm. or more. If the intestine is filled with dirt or other matter wash it out and observe the *typhlosole,* a fold which hangs into the intestine from the dorsal surface.

4. Make a full page drawing, dorsal view, of the digestive system found in the anterior part of the body, showing all structures mentioned above. In your drawing number all segments.

EXCRETORY SYSTEM

For a distance of several inches behind the clitellum open body wall as before and pin out flat. Remove the intestine carefully and notice the paired *Metanephridia* in each somite.

Each metanephridium is composed of two distinct parts located in different somites. The conspicuous white masses, one on each side of the nerve cord in each somite, are the *nephridial tubes*. Under the hand lens only a part of each mass shows its tubular nature. The tube leads forward to a transverse septum through which it passes and extends as a minute knobshaped *nephrostome* into the segment next ahead. The other extremity of the tube is attached to the body wall through which it opens as the *nephridiopore*. The location of this nephridiopore is best observed in the study of the cuticula under section IV. Note demonstration of stained nephridium. Draw three somites showing arrangement of nephridia as seen under hand lens.

RESPIRATION

In the earthworm there are no special organs for respiration. The moist conditions under which the animal lives and the delicate structure of the body wall make it possible for the entire body surface to function in the process of respiration.

NERVOUS SYSTEM

1. The *nerve cord* lies between the nephridia. Conspicuous thread-like structure, slightly enlarged in each somite. How many lateral branches in each somite, and where situated?

2. Notice the small, whitish, two-lobed *supra-pharyngeal ganglion*, or *brain*, at the anterior end of the pharynx and on its dorsal side.

3. Very carefully lift the posterior end of the pharnyx and trace the nerve cord forward to where it divides and passes around the pharynx to the brain, forming the *circum-pharyngeal collar*. Make a diagram of the nervous system.

BODY WALL

With the hand lens examine the cut surface of the body wall. Locate the muscle layers. Note the inner ends of the setae protruding through the body wall.

III. Study of Prepared Slides

Under the microscope examine cross sections of the body in the region of the intestine. Make an outline drawing of the cross section, properly oriented. This drawing should be 18 cm. in diameter. Show the exact structure of a strip 2 cm. wide from the center to the periphery and in addition show a portion of any other structures not included in this strip.

The following structures should be found: *cuticula* (may have been removed by handling previous to sectioning); *hypodermis,* an epithelium frequently showing darkly stained *unicellular mucus glands; circular muscle layer; longitudinal muscle layer.* Inside the body cavity find: the *dorsal vessel* with occasionally a lateral branch, one of the *parietal vessels;* the *intestine* with its *typhlosole;* the *nerve cord;* the *ventral vessel* which is connected with the intestine by a membrane—the *mesentery; nephridia* cut in various planes; *setae* or at least breaks in the musculature indicating location of setae.

IV. Study of Cuticula

Cuticula, the delicate iridescent outer covering. Strip off a piece of the cuticula from the anterior end of the body. Float it on a drop of water on a slide. Apply coverglass. Examine prepared slide with the microscope and find: the *seta sacs,* little sleeves within which the setae work; the *nephridial pores; openings of the mucus glands,* numerous very minute dark spots from which fine lines radiate; and the *covering of sense organs.* These last appear as small oval or rounded areas in which no mucus openings are present. Within these areas will be found groups of minute openings from which sensory hairs have protruded. Make a diagram of a complete segment showing the relations of these parts as viewed under low power.

REFERENCE

Sedgwick, W. T. and Wilson, E. B., 1904. An Introduction to General Biology. Henry Holt and Co.

CRAWFISH

(Materials: Tags, carmine, pins)

Classification:—Phylum Arthropoda, Class Crustacea, Order Decapoda.

This animal is studied as an example of a complex segmented animal, with diverse kinds of jointed appendages which are built upon the same general plan, and thus clearly illustrates the principle of homologies.

I. The Live Animal

1. Place a crawfish in a large dissecting pan and allow it to walk about. Determine the function of the different legs. Notes required on all questions upon live animal.

2. Place the crawfish in water and observe the movements of the *swimmerets* on the ventral side of the abdomen.

3. Note the use of the *tail fin* when the animal is suddenly surprised in the water.

4. Turn the animal upon its back and describe the method of righting itself. This experiment should be tried upon a rough surface.

5. Keep the crawfish in the air for a few minutes, then return it to the water, back downward, and describe where you find bubbles of air escaping.

6. Hold the animal, back downward, over a piece of white paper in the water and place a drop of carmine suspension on the ventral surface of the thorax in the region of the posterior pair of legs. Describe the result. What is the relation between what you observe and the bubbles, previously seen? The carmine is used simply to show presence of and direction of water currents.

7. Why are not air bubbles constantly ejected while the crawfish is in the water?

8. Make a diagram of a side view of the *carapace,* and show by arrows the general course of the water currents. Explain your diagram. Briefly summarize the method of aerating the gills.

9. Examine a demonstration specimen prepared to show the *"gill bailer"* in action. The "bailer" is a part of the *second maxilla.*

10. Observe to what degree the eye stalks are movable. What evidence can you give that the crawfish sees?

II. External Characters

1. Observe that the body is readily divisible into two regions. The large anterior region, which is covered on the dorsal and lateral surfaces by a non-jointed shell called the *carapace,* is the *cephalothorax.* The remaining series of movable segments behind the cephalothorax is the *abdomen.*

2. Note the *cervical groove,* a slight depression extending from the ventral margin to the dorsal surface of the carapace. This groove marks the boundary between head and thorax.

3. Examine the lateral margin of the carapace. This marks the ventral boundary of the *gillchamber.* On the dorsal surface of the carapace the gill chambers and pericardial chamber are separated by a pair of longitudinal grooves called the *branchiopericardial* grooves. The *rostrum* is the sharply pointed projection of the cephalothorax between the eyes.

4. Examine the ventral surface of the cephalothorax. Is there any evidence of segmentation? Notes required.

5. Note the texture of the skin. Where is it hard and where is it soft? What is the relation of the texture to movability? Notes required.

6. How many segments in the abdomen? How many have appendages? These appendages are called the *swimmerets.*

III. Homologies of the Appendages

In this entire section where drawings are asked for they are to be ventral views of the appendages from the left side of the body.

1. Study one *appendage* of the third abdominal segment. Distinguish the stem or *protopodite*, composed of a basal short segment the *coxopodite* and a long segment the *basipodite*. Of the two branches given off from the end of the protopodite the outer one is called the *exopodite*, while the one nearer the median line of the body is called the *endopodite*. Draw X4 and label all of the parts.

2. Such a two branched appendage is called a *biramous appendage*, and constitutes the general plan upon which all of the appendages of the crawfish are built. In the following study each appendage is to be studied in order to determine the modifications which have arisen in the various parts of biramous appendages.

3. The study of *homology* usually involves a comparison of organs or structures found in two different kinds of organisms. When repeated parts upon the same individual show the same fundamental plan of structure the term *serial homology* is used.

4. The terminal part of the abdomen is the *telson*. The telson together with the appendage of the sixth abdominal segment form the *tail fin*. Draw the entire tail fin X3, ventral view, labelling all parts and being especially sure to show what parts of the sixth abdominal appendage correspond to the parts worked out for the third appendage under section 1.

5. Remove carapace from the animal's left side exposing the gill chamber. Move the cheliped slightly and note relation to gills. With a pair of strong forceps grasp the cheliped at its attachment to the body and by a firm, steady pull remove the entire appendage, being sure to get all the parts belonging to it. The various parts of all such appendages are studied to best advantage when under water.

6. The appendages directly associated with the mouth opening have become greatly modified in their adaptations to special functions. In these highly modified appendages relative position of the parts is not a safe clue to homology. From the study of these structures in their early development it is usually possible to determine the homologies with certainty. In these and other obscure instances the information about the homologies is given in this outline.

7. With the cheliped out of the way it is easier to see the appendages immediately around the mouth. Before removing any other parts study the appendages just in front of the region from which the cheliped was removed. Note that there are three rather conspicuous *maxillipeds,* two smaller *maxillae,* and an extremely hard *mandible.* Between the mandibles and the first maxillae there is a pair of very small structures, the *paragnatha,* which occur at the sides of the mouth and form the posterior boundary of the mouth. They are outgrowths of the body wall and not true appendages.

8. A tabulated summary is of interest in showing the relationship of the parts in the variously modified biramous appendages of the crawfish. The following table is prepared as a summary of the study of the head appendages. A plus sign indicates that the structure is present, a zero that it is wanting.

segment appendage	exopodite	endopodite	protopodite	epipodite	gills
prostomium antennules	o	+	+	o	o
I. antennae	+	+	+	o	o
II. mandibles	o	+	+	o	o
III. first maxillae	o	+	+	o	o
IV. second maxillae	+	+	+	+	o

9. On your note paper prepare a table for the thorax and abdomen, using the same column headings as above. Data for filling out this table will be secured in the course of the study and should be incorporated into the table only after the study has been made as directed and after drawings that are asked for

have been prepared. The thorax includes segments V to XII and bears the three pairs of maxillipeds and five pairs of walking legs. The abdomen comprises segments XIII to XVIII and the telson.

10. In the same manner as directed above study the *third maxilliped* which lies immediately anterior to the cheliped. Examine carefully while still in place to make sure of proper arrangement of parts, then remove and draw ventral view, X4. Distinguish *protopodite* (made up of *coxopodite* and *basipodite*), *exopodite, endopodite, epipodite,* and *gills.*

11. Remove, study, and draw *second maxilliped.* Continue the study, using the *first maxilliped.* Draw. Do you find gills on each of these?

12. The *second maxilla* has a broad, thin protopodite near the median line of the body. The exopodite is a tough membranous structure, the gill bailer, which at its posterior extremity is continuous with another membranous projection, the epipodite. The endopodite is a very minute projection between protopodite and exopodite. Draw.

13. The *first maxilla* consists of only two conspicuous, flattened lobes, the outer one of which is the endopodite and the other the protopodite.

14. All the hard part of the *mandible* and the basal joint of the small feeler-like structure attached to its outer margin are protopodite. The two remaining segments of the feeler-like appendage are endopodite. Draw.

15. Examine the second pair of feelers, the *antennae,* and compare the parts with those of the third abdominal appendage. Draw left antenna X3. In this as well as in other parts of the outline the position of an appendage is determined by the point of its attachment to the body wall, not by the distance the appendage extends beyond the body.

16. Note the small white elevation on the ventral side of the basal joint of each antenna. The small opening in each of these elevations is the *excretory opening.*

17. The first pair of feelers, the *antennules,* though two branched are not 'biramous.' Their location upon the prostomium, which is not a true segment, their development, and their structure all indicate that they are not homologous with the other appendages. Note that three segments are interposed between the body and the two branches or *flagella* of each antennule, while but two segments are found in the protopodite of a true biramous appendage.

18. While the walking legs of the crawfish are not biramous in any stage of their development there are indications that they are biramous appendages which have lost the expodite. The crawfish is a near relative of the lobster but the development of the crawfish has been greatly shortened so that the young when hatched from the egg resembles the parent. On the other hand the lobster passes through a distinct series of free-living larval stages before acquiring the general body form of the adult. In these larval stages of the lobster the walking legs are typical biramous appendages made up of protopodite, expodite, and endopodite. During later development the exopodite disappears, leaving only protopodite and endopodite for each walking leg. These same parts are recognized in the walking legs of the crawfish.

Remove the walking legs and study to secure data for completing the table but no drawings are required.

19. The *genital openings* of the male occur on the basal segment of the fifth pair of walking legs, while those of the female occur in a similar position on the third pair of walking legs. Note that the first two pairs of abdominal appendages are different in the two sexes. Examine both sexes but no drawings are required.

20. In the male the first two pairs of abdominal appendages are highly modified for use in copulation and are not easily homologized. When at rest they lie in a groove directed forward between the bases of the walking legs. In the female the first pair of abdominal appendages is also modified. In the table asked for under section 9 do not try to work out the homologies for these modified structures of the first two or first abdominal appendages.

IV. Internal Organs

Circulatory System

1. With scissors cut away the dorsal surface of the carapace, by two cuts which extend from the hind margin forward toward the eyes, and connect anteriorly by a transverse cut. Do not injure the underlying parts when removing the cut part of the carapace.

2. Remove the delicate skin along the median line and expose the *pericardial sinus.* This cavity receives the arterial blood from the gills.

3. The *heart,* which lies within the pericardial sinus, is a thick walled muscular organ. It receives the blood from the sinus by three pairs of valvular apertures, the *ostia.*

4. What is the function of the circulatory system? Notes required.

5. Five vessels pass anteriorily from the heart. The median one is the *opthalmic artery.* On either side of this is an *antennary artery,* and from the broadest part of the heart are given off the *hepatic* arteries. Posteriorly from the heart runs the *dorsal abdominal artery* from which the *sternal artery* passes to the ventral surface of the body. This is an open circulatory system because in the tissues of the body the blood leaves the capillaries and finds its way back to the heart by way of a series of spaces called the *sinuses.*

6. Draw side view of heart and main branches of circulatory system.

Reproductive Organs

THE FEMALE

1. The *ovary* lies below the pericardial sinus, and frequently contains conspicuous *eggs.* There are two *anterior lobes* and a *median posterior lobe.*

2. From the lower side of the ovary trace the large *oviduct* downward to the external openings on the basal segment of the third pair of walking legs.

3. On the external surface upon the median line between the fourth and fifth pairs of walking legs observe the *annulus ventralis*. Following copulation sperm is stored in this until the time of egg laying.

THE MALE

1. The *testes* lie immediately below the pericardial sinus. They consist of two anterior lobes and one median posterior lobe.

2. The *vas deferens* is a long coiled tube extending along the side of the body, from the lower part of each testis to the genital opening, in the basal joint of the fifth walking leg. Before the breeding season has passed the vas deferens will be filled with a white mass of sperm.

3. Reexamine the appendages of the first and second abdominal segments, as it is by their aid that a tube is formed which conducts the sperm from the *genital openings* of the male to the *annulus ventralis* of the female. Make a drawing of the reproductive organs of your specimen.

See demonstration specimen of female crawfish carrying eggs on the swimmerts. The eggs, after fertilization, become attached to the swimmerts were they undergo development.

Digestive System

1. The digestive tube extends from the mouth to the anus. The *liver* (or more correctly the *hepato-pancreas*) is a large bilobed organ which lies below the ovaries or testes. These lobes lie along either side of the digestive tube. Each lobe connects by a duct with the main digestive tube.

2. Turn the animal over and on the ventral side examine the mouth between the jaws. Insert a probe into the *mouth*.

3. A short wide passage, the *esophagus,* leads upward from the mouth.

4. The esophagus leads to a large dilated portion of the canal, *the stomach.* This occupies the main portion of the head region. The larger *cardiac chamber* lies in front and the smaller *pyloric chamber* lies behind. The two are separated by a narrow constriction.

5. The region of the mouth, esophagus, and the stomach are lined with chitin and are formed by an infolding of the outer skin of the animal as it develops. These parts are collectively known as the *stomodaeum.*

6. Posterior to the stomodaeum is the *mesenteron.* This part lacks the chitinous lining and receives the ducts from the liver.

7. The *proctodaeum,* which leads to the anus, is the part of the digestive tube behind the mesenteron. Trace its course. This is lined with chitin, and develops from an infolding of the outer surface.

8. Make a drawing twice natural size of a side view of the entire digestive system. Label all the parts.

9. Remove the stomach and carefully examine the *gastric mill.* Cut longitudinally through the ventral wall and examine the interior after pinning it out expanded. Distinguish the *cardiac* and *pyloric chambers,* and the constricted region of the *gastric mill.* What do you infer to be the main function of this mechanism? Notes required.

10. The *cardiac ossicle* is a hard plate running across the roof of the cardiac chamber.

11. The *median tooth* is at the junction of the pyloric and cardiac chambers. Note the *lateral teeth.*

12. Manipulate these teeth to see how they crush the food.

13. The aperture between the cardiac and pyloric chambers is much narrowed by folds, as is also the entire pyloric chamber.

These folds are fringed with hairs so that they form a strainer or *filter* which prevents the passage of large food particles into the intestine. Make drawing of gastric mill as dissected.

14. Manipulate the mandibles and learn where the large muscles are attached. Distinguish the *tendons.*

Nervous System

1. The *central nervous system* consists of a chain of paired *ganglia* extending the length of the body close to the mid-ventral line. The ganglia of a pair are so closely applied that they appear as a single ganglionic mass. Locate the nerve chain near the base of the abdomen. Trace it forward along the floor of the thorax to a point where it enters a small canal. With a pair of forceps pick away the parts of the *endophragmal skeleton* which form the canal surrounding the nerve chain.

2. The *brain* or *pre-esophageal mass* is a rather large white body just behind and above the bases of the antennules. This supplies *nerves* to the eyes, antennae, and antennules.

3. The *para-esophageal connectives* are a pair or nerve cords which connect the brain, around the esophagus with the hinder part of the nervous system. Behind the esophagus they are connected by a *transverse commissure.*

4. The *post-esophageal* mass lies behind the mouth. It supplies the mandibles, maxillae, and first and second maxillipeds with nerves.

5. The thoracic nerve chain consists of six ganglionic masses, which supply nerves to the third maxillipeds and the five pairs of walking legs. The first one lies very close behind the post-esophageal mass.

6. Trace the *abdominal nerve chain* with its six ganglionic masses.

7. Make a drawing to show the nervous system and label all parts.

8. A *statocyst* occurs on the dorsal surface of the basal joint of each antennule. Remove the rostrum and locate opening of statocyst by means of a blunt probe.

Excretory System

1. The kidneys or *green glands* lie in the ventral part of the head anterior to the mouth. Each kidney connects with the exterior on the posterior surface of a tubercle located upon the basal segment of the antenna.

References

Andrews, E. A., 1906. The Keeping and Rearing of Crawfish for Class Use. Nature-Study Review: Vol. 2, pp. 296-301.

Herrick, F. H., 1911. Natural History of the American Lobster. Bull. U. S. Bureau Fisheries 29.

STARFISH

(ASTERIAS)

Classification:—Phylum Echinoderma, Class Asteroidea.

The starfish will be studied as a representative animal in which the organs are duplicated, more or less perfectly, about a central axis, and therefore it is said to be radially symmetrical. During this study look for structures which prevent the starfish from being a perfectly radial animal.

As this kind of animal differs so much in structure from the other animals you have studied it will be very important to keep in mind the functions of the different organs, as functional relations to other animals are more readily understood than its structural relations.

The entire study, including the dissection, must be made from a single specimen.

I. External Characters

1. Observe the *oral* surface (the surface with the mouth).

2. The *aboral* surface. How do the two surfaces differ?

3. The *central disc,* from which the *arms* or *rays* radiate.

4. Find the *sieve plate* or *madreporic plate,* a small round area without spines, on the disc between the two rays which form the *bivium.* Examine the madreporic plate with a hand lens. Draw X5.

5. Opposite the madreporic plate is the *anterior ray,* which with the one on each side of it forms the *trivium.*

6. Note the spines scattered over the surface of the animal. Are they uniform in distribution?

7. The *anus,* or external opening of the digestive system, is located upon the disc. It is a *vestigial organ* and can not ordinarily be found.

8. The fleshy protuberances between the spines, the *gills,* are hollow finger-like processes which connect with the body cavity and in which the body fluid circulates. Sea water bathing the outer surface of the gills furnishes the necessary oxygen to aerate the fluid within.

9. The *pedicellariae,* small pincer-like organs, protect the animal, and especially the gills, from injury and remove debris. They are especially abundant about the bases of the spines. Find them. Examine a prepared slide of pedicellariae under the microscope. Find and draw two distinct kinds. In the larger type the basal portion is a distinct piece upon which the two jaws are hinged while in the smaller type the basal parts of the two jaws cross over each other like the handles of a pair of shears or tongs.

10. A line drawn from the center of the disc along the middle of an arm is a *radius.* One drawn from the same point exactly between two arms is an *inter-radius.* Do all radii inter-

sect similar parts? All inter-radii? Are radii or inter-radii marked in any way on the aboral surface of animal? Notes required.

11. Make an outline drawing of the aboral surface showing details on the disc and a portion of *one* ray only.

12. With the oral surface uppermost notice:—

The *mouth.* Position? Size? Is its margin smooth or rough? Note the clusters of spines projecting over it. Are they radial or inter-radial?

The *peristome* or membrane surrounding the mouth.

The *ambulacral grooves.* One runs outward along the ventral surface of each ray. They contain:—

The *ambulacral feet* or *tube feet.* Note their terminal suckers.

Draw the oral surface showing details of the disc and one ray. In determining the arrangement of the tube feet pull off the feet from a portion of one groove and note the openings from which the feet protruded.

II. Internal Organs

Remove, under direction, the aboral wall of the anterior ray and the disc, being very careful to leave undisturbed those portions directly beneath the wall of the disc and in the vicinity of the madreporic plate.

The Digestive System

Note how the *pyloric ceca* are attached to the aboral walls of the arms and how the stomach is attached to the aboral wall of the disc. Note further:

1. *Intestine,* a very short tube, extending from pyloric sac to anus.

2. *Intestinal ceca* opening into the intestine. How many lobes?

3. The *pyloric cecum* is the conspicuous two branched structure occupying most of the space within each ray. This organ produces digestive fluids. At its inner end each cecum is attached to the *pyloric chamber of the stomach.*

4. *Pyloric sac* or stomach. Shape? Position? How attached to body wall? How many and what openings from it? Into it?

(*Extensor muscles of rays.* Situated in the center of the lower face of aboral wall of each ray. What movement can be produced by their contraction?)

5. *Cardiac division of the stomach.* Remove the ceca from two adjacent rays and under the corner of the pyloric sac note one of the five cardiac pouches, the union of which makes the cardiac stomach.

6. *Stomach retractor muscles.* There are two to each pouch. Attachments? What effect would their contraction have? Notes required.

7. *Esophagus.* Cut two of the stomach retractors and raise up the pouches so as to expose the esophagus.

8. *Peristome* or membrane around the mouth. Expose from inside.

9. Make a careful drawing showing the digestive system from aboral surface.

10. Study the chart and your specimen to make out the relations of these organs in side view.

Reproductive System

The sexes are distinct. Have the reproductive glands pointed out to you. Number in each ray? Position? Form? Examine with a lens. Their ducts may be traced into the inter-radial partitions whence they pass up to the openings on the upper surface of the rays. Their external openings are very difficult to demonstrate.

Nervous System

Pull off all the tube feet and interambulacral spines from one ray and note:—

1. The *radial nerves,* one at the bottom of each ambulacral groove. Trace it down to the peristome and find its connection with—

2. *The cirum-oral nerve ring.*

3. Each radial nerve ends at the tip of the ray in an *eye spot* which is brightly colored in living animals but usually inconspicuous in preserved specimens.

Make a diagram of the nervous system.

Water Vascular System

1. The *stone canal* extends down from the sieve or *madreporic plate.* Shape? Nature of its walls? Connection of its lower end with the *circum-oral canal?*

2. *Ambulacral* or *tube feet.* Position?

3. *Ampullae.* Occur inside the body cavity. Number of rows? Are they connected with tube feet?

4. *Radial canals* or *water tubes.* One on the aboral side of each radial nerve band. Expose one by scraping away a radial nerve.

Make out the connections between the different parts of the water vascular system. Draw the water vascular system of the disc and one ray. Can you think of possible uses for it? State your views and have them criticized before incorporating them in your notes. How does the animal crawl? Notes required.

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FRESH-WATER MUSSEL

(Materials: aquaria, carmine suspension.)

Classification:—Phylum Mollusca, Class Acephala.

The mussel is studied as an example of a highly developed group of animals which are entirely without segmentation.

I. The Live Animal

1. Note the general appearance and position of the animal when fully extended.

2. Identify the fleshy *foot,* and the *two valves* which comprise the shell. Note the gaping valves caused by the tension of the *hinge ligament.*

3. The foot projects from the lower *(ventral) anterior* part of the shell and the *hinge* line is on the *dorsal* surface.

4. At the posterior end of the animal distinguish the *inhalent aperture* by means of carmine suspension. Determine the function of this opening. Is there an *exhalent aperture?* If so, give the evidence for this. Notes required.

5. Examine the *demonstration* of a fragment of a gill under the microscope and observe the movement of the cilia. How is the water current produced? What are its main functions? The food of the mussels consists primarily of microscopic plant forms (plankton) and particles of organic matter suspended in the water.

6. Make an outline drawing, natural size, of the expanded condition of the animal and name all parts.

7. From an assistant learn how to cut the *adductor muscles.* Cut free the *mantle* from the pallial line and remove the *left valve* of the shell.

8. Below the hinge line of the shell is found a slowly pulsating organ, the *heart.* Carefully cut through the surrounding *pericardium,* and expose the heart. Distinguish the median *ventricle* and the lateral *auricles,* the left one being uppermost.

9. Examine the left valve of the shell and distinguish the *scars* on the valve where the anterior and posterior adductor muscles were attached.

10. Examine the *pallial line* and note the corresponding part of the *mantle.* The *mantle muscle* and its mode of attachment may be seen on the right side of the animal. Compress the margin of the right mantle. What is the effect? What is the function of the mantle muscle? Notes required.

11. Distinguish the *umbo* near the anterior part of hinge ligament. This is the older part of the shell, and concentric with this are the lines of growth. How are these formed? What do they indicate? Where is the newest part of the shell?

II. The External Characters of the Soft Parts

1. Examine the soft parts of the mussel on the *"half shell."* Compare the cut muscles on the body with the scars on the shell, and also with those yet in place on the right side. Distinguish the following muscles and their scars:

(a) The large *anterior adductor,* near the dorsal anterior end. Posterior to this is a pair of muscles:—

(b) The *anterior retractor* is the upper or dorsal one;

(c) The *protractor* is the lower or ventral one. The *protractor* compresses the *visceral mass* and forces the foot from the shell. Determine the functions of the other muscles. At the posterior end are:

(d) The large *posterior adductor.*

(e) Dorsal and anterior to the preceding is the *posterior retractor.*

(f) The *mantle muscle* is attached along the pallial line.

2. Note the right and left *mantle lobes* and their relation to one another.

3. *Note the inhalent* and *exhalent apertures* and the margins of the mantle in this region.

4. Fold back the *left mantle lobe* and distinguish the two *gills* just beneath the mantle; the *foot,* a heavy muscular structure; the *visceral mass,* the enlarged region dorsal to the foot; the *labial palpi* two small triangular flaps at the anterior end of the body.

5. Make an outline drawing of the left side, with the shell and mantle removed, to show the relation of parts. Label all parts.

6. Pass a probe into the exhalent aperture and note the cavity, the *cloaca,* which lies above the bases of gills and posterior to the posterior adductor muscles. Above the muscles is the *anal opening* of the intestine. The portion of the intestine leading to the anus is the *rectum.*

7. Insert a probe into the mouth, which lies between the anterior adductor muscle and the anterior edge of the foot. Determine the relation of outer and inner pair of palpi to the mouth.

8. Determine the relation of the two pairs of glils to one another. The gills may be distended with eggs and larvae in some specimens. Locate the *supra-brancial chamber* and determine its relation to the exhalent aperture.

III. Examination of Cross Sections

1. Cut a section, about ¼ inch thick, obliquely through the anterior part of the pericardial cavity and the foot. Distinguish the mantle, gills, visceral mass, intestine, foot, rectum and its typhlosole, and ureter. Draw and label all the parts.

2. Make a similar section through the region of the posterior adductor. Determine the relation of the suprabranchial chamber. Draw.

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GLOSSARY

Terms which are fully defined in the text are not repeated in this list.

Aboral surface—The surface opposite the one bearing the mouth.

Ambulacral area—The series of skeletal plates bearing the openings through which the tube feet protrude.

Ampullae—Small, sac-like reservoirs connected with the tube feet of echinoderms; located inside the body cavity.

Anterior—That part of the body normally directed forward in locomotion.

Anus—The posterior opening of the alimentary canal for the discharge of waste.

Asexual reproduction—Any form of reproduction not involving the functioning of germ cells.

Asymmetrical—Parts of the body arranged irregularly so that no plane could divide the body into equal parts with corresponding structures on the two sides of the plane.

Bilaterally symmetrical—Parts of the body evenly disposed on the two sides of a plane which passes through the chief axis of the body. One-half of the body is the mirror image of the other half.

Bivalve—A shell composed of two approximately equal parts hinged one on the other.

Blastula—That stage in the development of a fertilized egg when the cells resulting from cleavage become arranged in a single layer usually surrounding a cavity.

Budding—A method of asexual reproduction in which a small portion of the body gives rise to a new individual.

Carapace—The shell covering the dorsal and lateral surfaces of head and thorax of a crawfish.

Caudal—Located at the posterior tip of the abdomen.

Cephalothorax—A term applied to the anterior part of the body of an animal in which head and thorax are not separated from one another.

Chela—The large claw of a Crustacean.

Cleavage—The division of cell following the division of the nucleus.

Cloaca—The posterior region of an alimentary canal that holds the waste from the digestive and excretory organs.

Coelenteric cavity—The single cavity of the body of a coelenterate which at the same time serves as body cavity and digestive cavity.

Conjugation—The fusion of two protozoans for an exchange of cytoplasm or of nuclear material.

Cuticula—A thin, non-cellular body covering of many invertebrates.

Differentiation—The specialization of a group of cells for a definite, restricted function.

Dorsal—"The back;" or more strictly the part of the body directed away from the surface upon which the animal normally rests.

Elytra—The horny outer wings of the Coleoptera.

Fertilization—The fusion of two gametes to form a single cell, the zygote.

Fission—A method of asexual reproduction in which the body of an individual becomes split into two equal parts.

Gamete—A reproductive cell.

Gastrula—That stage in the development of a new individual from a fertilized egg in which the cells resulting from cleavage become arranged in two layers.

Invasion—A term used in ecology to denote the entrance of new species into a habitat, usually due to changes produced by species already present.

Labium—The lower lip of an arthropod.

Larva—A young, free-living animal which has not yet completed its development.

Lateral—Of or pertaining to the side of the body.

Left—The lateral surfaces of any animal's body are determined by placing the animal in a position comparable to the position of the observer (i. e., with the anterior end uppermost and with the dorsal surface toward the observer). Then left and right of the animal correspond directly to left and right of the observer.

Longitudinal section—A section taken to include the main axis of the body or parallel to the main axis.

Madreporic plate—A finely perforated disc at the external opening of the water vascular system of echinoderms serving to keep out foreign matter.

Matrix—A non-protoplasmic substance in which the cells of some tissues are embedded.

Metamorphosis—A marked change in an animal between the time of hatching from the egg and acquiring adult body form, involving the loss of some structures characteristic of the larva and the acquisition of new structures characteristic of the mature adult.

Metazoa—"Many-celled animals;" all animals higher than the Protozoa.

Nymph—The young of those insects which at the time of hatching resemble the adult except for the lack of certain adult

organs. The young of insects having incomplete metamorphosis.

Oral surface—The surface on which the mouth is located.

Organ—A group of cells or tissues which together perform some specific function.

Pellicle—A thin, non-living cell wall covering the body of most Protozoa.

Plane of symmetry—Any plane which passed through an object divides the object into two parts of corresponding size and form.

Posterior—At or toward the hinder end of the body.

Prolegs—Larval legs, without joints, upon the abdomen of some insect larvae.

Pseudopodium—Temporary protoplasmic process thrust out from membraneless cells.

Pupa—The inactive stage between the larva and adult of insects having a complete metamorphosis.

Rayed fin—A fin, the membrane of which is supported by a series of spines or 'rays.'

Right—(See definition of left.)

Regeneration—The power of an organism to replace a lost part.

Rudimentary—Any organ or structure which has not yet reached its full development.

Segment—One of the successively repeated units of the body of a jointed animal.

Seta—(pl. setae): stiff "hairs" or bristles.

Somite—One of the divisions of the body of a segmented animal.

Spiracles—External openings of the respiratory system of insects.

Stalked—Extending beyond the margin of the body at the tip of a stalk.

Stipple—A method of portraying structure by the use of fine dots.

Succeed—(See succession.)

Succession—A term used in ecology to indicate the change in species present at any one point due to changes produced by organisms there or due to physiographic causes.

Symmetrical—Parts of the body arranged in regular order with reference to one or more axes or planes.

Tarsal claws—One or more claws or hooks at the end of an insect's foot.

Tarsus—(pl. tarsi): the foot.

Thorax—In arthropods and vertebrates that part of the body between the head and abdomen, usually bearing appendages.

Tissue—A group of similarly differentiated cells.

Tracheae—Air tubes within the body of an insect, serving for respiration.

Transverse section—A section taken at right angles to the main axis of the body.

Umbo—The protuberance of a bivalve shell above the hinge ligament.

Ventral—"The under side of the body;" or more strictly that part of the body directed toward the surface upon which the animal walks or comes to rest.

Vertical section—A section running from dorsal to ventral surface through the main or chief axis of the body.

Vestigial—Any organ or structure which never reaches full development and is consequently without function.

Wing-pads—Rudimentary, sac-like wings on the thorax of many nymphs.

Zooid—One of the individuals in a united colony of animals.

Zygote—A single cell resulting from the fusion of two gametes.